

Suggested Template Plan for Forward Intensity Modulated Radiotherapy in Head and Neck Cancer Patients

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Abstract

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Background: We aimed to achieve full tumor control during every fraction with head and neck cancer patients using 3DCRT treatment technique.

Method: We divided 16 head and neck cancer patients into two groups to deliver radiotherapy doses of 66Gy and intensity modulated radiotherapy (IMRT) 70Gy. We applied 3DCRT plan as a forward IMRT plan for each patient with coplanar beams arrangement technique designed with angles of (0o, 60o, 90o, 180o (or around 175o and 185o), 270o and 300o). We assessed the plans according to DVHs and satisfactory dose distributions.

Results: Based on the overall evaluation of the two groups (16 cases), we achieved an accepted dose distribution for PTVs and OARs dose; simulating IMRT inverse plans dose distribution.

Conclusion: Using such a mono-isocentric plan, we were able to achieve a perfect uniform dose distribution for PTVs up to 70Gy, while sparing critical organs. This template could be used in countries with no access to forward IMRT planning.

Keywords: 3DCRT, Radiotherapy, Intensity modulated, DVH, Neoplasms, Dosimetry

Introduction

Treatment strategy was developed from field shaping with customized blocks (a procedure that becomes impracticable with the increase in the number of beams and directions)

to field shaping using multileaf collimators (MLCs). Regarding complex tumor shapes such as target volumes that contain invaginations, internal hollows, and bifurcations, 3-DCRT techniques cannot

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sufficiently generate conformal dose distributions.¹ Conventionally, dosimeters such as ionization chambers, diodes, and thermoluminescent dosimeters (TLD) are utilized for dose verification in one point, while diode/ionization chamber arrays or films are applied to dose verification in one plane. In 3D, one can use multiple films, several array measurements, or gel dosimetry. Prior to the treatment, all fields for an intensity modulated radiotherapy (IMRT) treatment should be verified using one of the methods described above. The verification of the IMRT plan is much more time-consuming than that of conventional plans. Unlike conventional methods, IMRT delivers radiation beams that are effectively divided into multiple beam lets with several intensities as planned allowing for a perfect control for patients.² Therefore, when optimization process and the number beam lets with different intensities are chosen to be used, IMRT plan results in high tumor control decreasing normal tissues toxicity.³ Optimization factors are determined for better results based on delivered doses to organs and their biological effects. For better results, deviations from the optimization tips, that can cause IMRT plan problems, have to be minimized during the optimization process.⁴ All IMRT solutions were applied to lower maximum or mean doses of organs at risk (OAR) such as spinal cord, parotid, and larynx.^{1,5} In certain treatment sites, several authors aimed to spare heart, which is best achieved with IMRT.⁶ IMRT could be used in some limited situations to treat breast, thyroid, lung, gastrointestinal, gynecologic malignancies, and some types of sarcoma. EPID is used to measure LINAC beam parameters such as collimator center of rotation and matching of radiation fields with light fields; they are also employed for quality assurance and designation of compensators.⁷ A medical physicist calculates the IMRT plans for exposure and defines the necessary beam configuration required to accurately deliver the dose prescribed by the radiation oncologist. Finally, the medical physicist verifies the treatment plan on the linear accelerator using measurement tools (in vivo dosimetry) prior to delivering this plan to patient.^{7, 8}

Methods

Patient selection and delineation

We utilized 3DCRT plans as forward plans to treat 16 patients. We tried to find a manual template for irradiating locally advanced head and neck cancers to help physicists make their final plan through using it as a platform. We selected 16 cases with different head and neck cancer subsites (nasopharynx, tongue, and larynx), applied this template plan, and assessed the coverage of different target volumes, while sparing the OAR to test our template plan. All the cases received lymph node irradiation. We delineated the target volumes and organs at risk according to clinical indications. We divided the patients into two groups according to the prescribed dose. The first group included nine patients receiving three dose levels (ctv70, ctv60, and ctv54), and the second group comprised seven patients treated with lower dose levels (ctv66, ctv60, and ctv54).

Nasopharynx: GTV70: We included all gross diseases in the physical examination and imaging with any lymph node more than one centimeter or with necrotic center. CTV 70: We added a margin of 5 mm except at critical OAR (brain stem, optic nerve, or optic chiasm) and used the minimum expansion which might reach 1 mm. PTV 70: 5 mm expansion around the CTV was the margin recommended to form PTV. CTV 60: We included the entire nasopharynx anterior 1/3 of the clivus (entire clivus, if involved), skull base (foramen ovale and foramen rotundum), pterygoid fossa, parapharyngeal space, inferior sphenoid sinus (entire sphenoid sinus in T3–T4 disease), posterior 1/4 of the nasal cavity/maxillary sinuses (with pterygopalatine fossa coverage), inferior soft palate, retropharyngeal lymph nodes, retrostyloid space, bilateral nodal levels IB through V. PTV 60: 5 mm expansion around the CTV60 except at brain stem where the minimum margin was only added (down to 1mm). CTV54: Included node negative neck or low neck nodes (levels IV and VB). Tongue cancer: We performed radiotherapy as adjuvant postoperative indication. Ctv66: We covered the preoperative tumor volume, areas of positive margin, soft tissue or

Table 1. Planning main arrangements and techniques for the upper part of the plan covering the tumor bed of phase 54

Field ID	Machine Energy	Field Weight	Gantry Rotation	Wedge
Anterior	6MV	0.74	0	None
Lt Lateral	6MV	0.28	90	W30L20
Ant Lt Lat Oblique	6MV	0.6	60	W30L20
Rt Lateral	6MV	0.28	270	W30R20
Ant Rt Lat Oblique	6MV	0.6	300	W30R20
Rt Posterior	6MV	0.28	190	None
Lt Posterior	6MV	0.28	170	None

Left (Lt), Right (Rt), Wedge 30 (W30), Mega Volt (MV)

bone invasion, and extra-capsular nodal extension. Ctv60: Preoperative gross disease at the primary site or lymph nodes with the inclusion of bilateral cervical lymph nodes from level I to level IV. Ctv54: Ipsilateral or contralateral lymph nodes with low risk for subclinical diseases. Laryngeal cancer: We performed radiotherapy in locally advanced cases as a definitive line of treatment. Ctv70: We included the primary tumor and the involved lymph nodes. Ctv60: We covered the entire larynx, involved and adjacent nodal levels, indeterminate nodes, and stoma if present. Ctv54 was the target for elective nodal irradiation. OAR: We delineated all organs at risk in all cases. These included both parotid glands, spinal cord, eyes, lenses, optic-nerves, optic chiasm, brain stem, and both cochleas.

Beam arrangement

We employed the applied 3DCRT plan as forward plan for each patient with coplanar beams arrangement technique designed by angles of (0o,

60o, 90o, 180o (or around 175o and 185o), 270o and 300o). We did not utilize 15MV energy in combination with 6MV except in the case of extreme need to control the entrance and the exit dose while planning. Tables 1 and 2 show the planning main arrangements as weights of fields were distributed according to gantry angles for fields of the upper and lower parts of phase 54 plan.

We defined the normalization point so as to gain the dose of 100% at the plan isocenter. We placed the treatment isocenter exactly on the next slice after the end of tumor bed margin (PTV 60) where the left and right lymph nodes delineation were separated around the spinal cord (PTV 54). Afterwards, we separated the plan into two sub-plans, one higher on the part of PTV60 and PTV70 but the other lower part on both sides of Lymph nodes PTV54; we noticed the following different beam eye views for different patients in figure 1; the two parts were with the same gantry angles but separated as half beam blocks to avoid

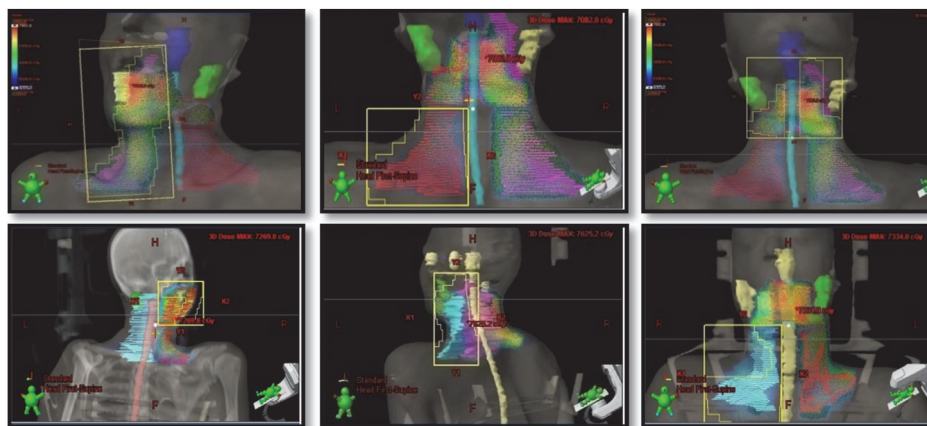


Figure 1. This figure shows different beam eye views showing the plan isocenter.

Table 2. Planning main arrangements and techniques for the plan lower part that covers lymph nodes of phase 54

Field ID	Machine Energy	Field Weight	Gantry Rotation	Wedge
Lt Anterior	6MV	1.16	0	None
*Lt Anterior segment	6MV	0.15	0	None
Rt Anterior	6MV	1.16	0	None
*Rt Anterior segment	6MV	0.15	0	None
Ant Lt Lat Oblique	6MV	0.65	60	W30L20
Ant RtLat Oblique	6MV	0.65	300	W30R20
Rt Posterior	6MV	0.7	195	None
*Rt Posterior segment	6MV	0.2	180	None
Lt Posterior	6MV	0.7	170	None
*Lt Posterior segment	6MV	0.2	180	None

Left (Lt), Right (Rt), Wedge 30 (W30), Mega Volt (MV); *We added segments to improve the dose distribution; we preferred to use the same angles of main fields decreasing the time required for one session.

generating hot areas due to overlaps and areas of double dose.

When we finished phase 1 as discussed before, we prepared phase 2 by use of the same plan for phase 1 but excluding the lower part of plan treating the left and right lymph nodes part (PTV 54Gy/27Fr). We conformed MLCs again to margin around the target volumes (PTV60 that includes PTV70) to give a dose of 600cGy/3Fr. We checked the dose distribution and organs at risk dose prior to finishing this plan. Tables 3 and 4 show the planning main arrangements as weights of fields were distributed according to gantry angles for fields of the upper and lower parts of phase 60 plan.

We designed phase 3 at the same isocenter of phase 1 and 2 with the usage of the lowest acceptable number of beams that prevents excessive threshold tolerance doses for OARs; here, we applied 10Gy/5Fr dose for this plan to

complete the overall dose to 70Gy/35Fr after phase 1 and phase 2 doses. After we finished the three phases, we set plan sum for phase 1, phase 2, and phase 3. Table 5 shows planning main arrangements for phase 70 plan, which includes fields weight and gantry angles used, that will vary according to PTV 70 delineation and the nearby OARs.

Results

We evaluated the three summed plans according to the defined acceptance criteria. We dealt with hot and cold areas that needed to be corrected to obtain uniform dose distributions. We controlled these areas by inserting fields in field with weighting dependent on hot or cold areas to compensate doses; this might add a number of field shapes with MLC, while still not changing the gantry angles. We applied this method on the Eclipse planning system (version

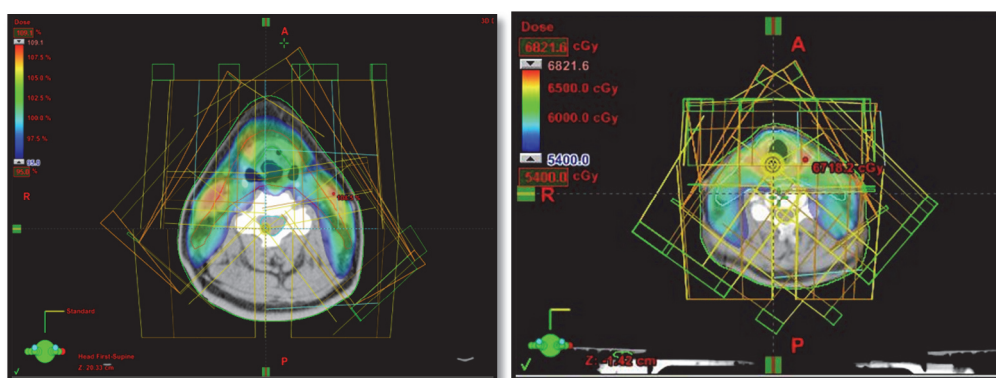


Figure 2. This figure shows accepted plans dose distributions as an example for two different cases planned with Eclipse planning

Table 3. Planning main arrangements for the upper part of the plan covering the tumor bed of phase 60

Field ID	Machine Energy	Field Weight	Gantry Rotation	Wedge
Anterior	6MV	0.76	0	None
Lt Lateral	6MV	0.28	89	W30L20
Ant Lt Lat Oblique	6MV	0.6	55	W30L20
Rt Lateral	6MV	0.28	268.8	W30R20
Ant RtLat Oblique	6MV	0.6	305	W30R20
Rt Posterior	6MV	0.26	190	None
Lt Posterior	6MV	0.26	170	None

Left (Lt), Right (Rt), Wedge 30 (W30), Mega Volt (MV)

10.0) and Prowess panther (version 5.20).

In Prowess planning system, we had to create different calculation points for every set of beams to be in the opening area (not blocked by the jaw or by MLCs) to complete the dose calculation as expected with attention to field's weight covering our target without the undesired hot or cold dose areas, as previously discussed. More than 85% of calculated plans were accepted for treatment. Figure 2 is an example for summed plans and accepted dose distributions, showing two different cases treated with the designed plan on Eclipse planning system.

We used the same 3DCRT plan as an inverse plan for the two groups of patients (different PTVs and OARs) with the same dose distributed into three phases for each group (one group with a total dose of 66Gy and another group with a total dose of 70Gy). We were able to achieve perfect uniform dose distribution for PTVs up to

70Gy, while sparing critical organs, including spinal cord, brainstem, eyes, optic nerves, and parotid glands using this technique with the same gantry angles as a template plan. The obtained acceptance criteria were brain stem (whole organ) $D_{max} < 54\text{Gy}$, spinal cord (whole organ including full cord cross-section) $D_{max} = 50\text{Gy}$, optic nerve / chiasm $D_{max} < 55\text{Gy}$ (given the small size, 3DCRT is often whole organ), eyes $D_{max} < 50\text{Gy}$, lens $D_{max} < 8\text{--}10\text{Gy}$, bilateral whole parotid gland mean dose $< 25\text{Gy}$ (for combined parotid glands), and unilateral whole parotid gland mean dose $< 26\text{Gy}$ (for single parotid gland, at least 50% of one parotid spared to $< 30\text{Gy}$).

We changed the isocenter position and slightly varied the field's weights depending on the patient geometry and organs delineation (PTVs, LN, and OARs). Figure 3 shows the different sagittal and frontal views for the summed plans with accepted dose distribution examples for different planned

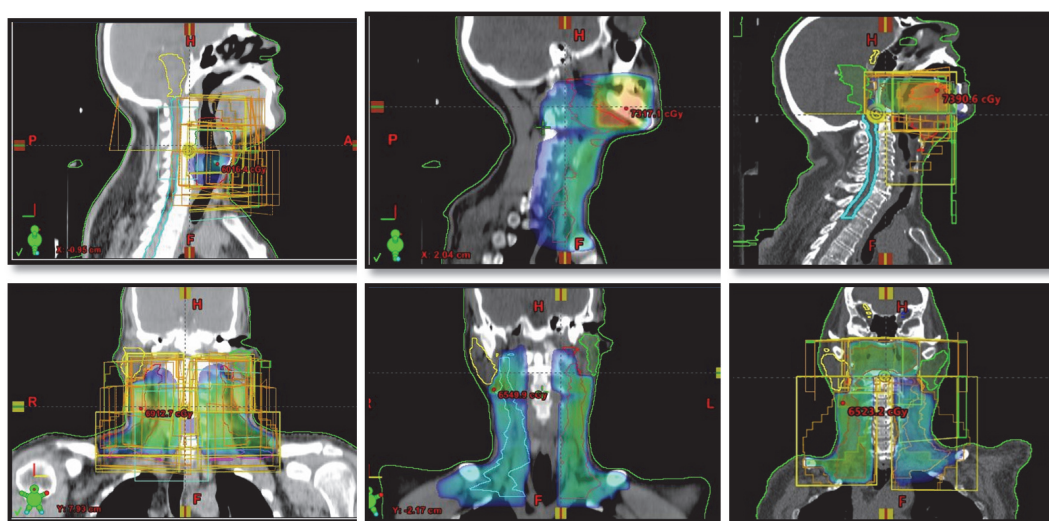


Figure 3. This figure shows different sagittal and frontal views for various accepted plans with dose distribution examples.

Table 4. Planning main arrangements for the lower part of the plan covering the lymph nodes of phase 60

Field ID	Machine Energy	Field Weight	Gantry Rotation	Wedge
Lt Anterior	6MV	0.9	0	None
Rt Anterior	6MV	1.16	0	None
*Rt Anterior segment	6MV	0.1	0	None
Ant Lt Lat Oblique	6MV	0.65	60	W30L20
Ant Rt Lat Oblique	6MV	0.65	300	W30R20
Rt Posterior	6MV	0.7	195	None
*Rt Posterior segment	6MV	0.15	183	None
Lt Posterior	6MV	0.7	170	None
*Lt Posterior segment	6MV	0.15	183	None

Left (Lt), Right (Rt), Wedge 30 (W30), Mega Volt (MV)

cases.

Of note, due to the dose fall off from the higher dose PTV, it is expected that the PTV with lower prescribed dose to receive a higher median dose. We accepted 16 planned and treated cases for treatment with the same plan design after assessing the mean and maximum dose for PTV 54Gy, PTV60Gy, PTV66Gy, and PTV 70Gy and OARs dose (spinal cord max, brain stem max, Rt parotid mean, Lt parotid mean, Rt optic nerve max, Lt optic nerve max, Rt eye max, and Lt eye max).

Discussion

The results showed a better control on tumors and sparing of the surrounding healthy tissue and risky structures in the area under treatment, leading to better quality control of patient's life. IMRT and conformal treatment planning methods are more complex and time-consuming than conventional methods. Due to the complexity of its treatment plans, the actual treatment session of IMRT is much longer than a conventional treatment session. Owing to the high precision and immobilization ability and stable fixation

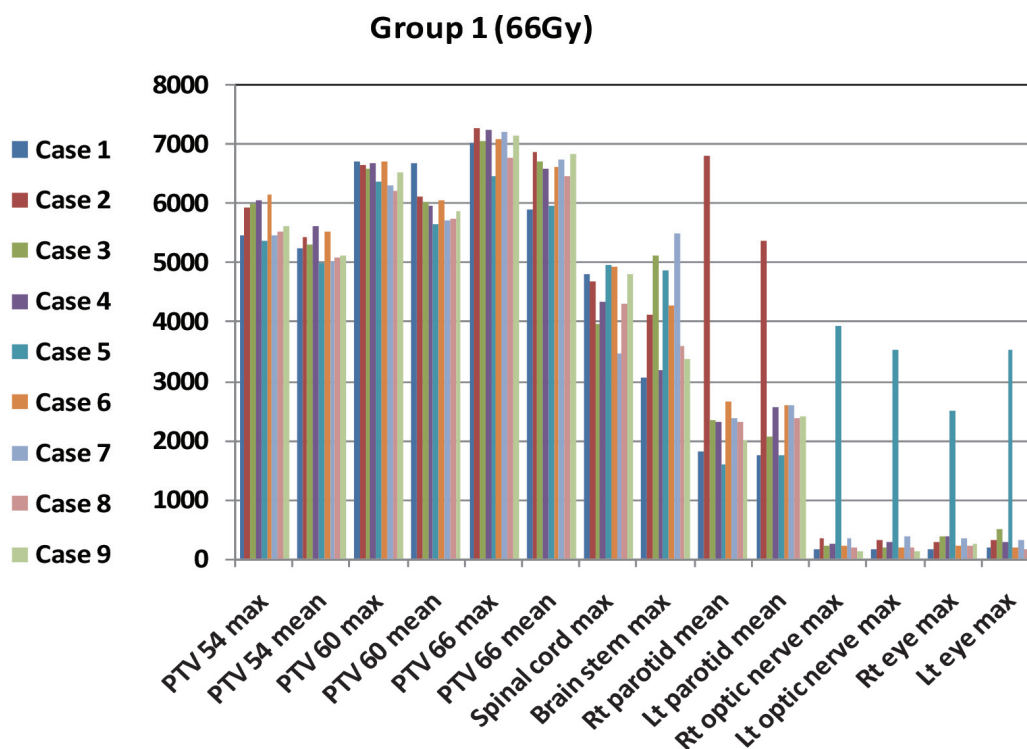


Figure 4. This figure shows group (1) planning data for PTV54, PTV60, PTV66 and doses of OARs.

Table 5. Planning main arrangements for phase 70 plan

Field ID	Machine Energy	Field Weight	Gantry Rotation	Wedge
Field 1	15MV	1.0	37	None
Field 2	15MV	1.0	217	None

Mega Volt (MV)

systems, the other surrounding normal tissues receive minimum doses of radiation, hence able to regenerate faster with fewer damages than tumor cells.

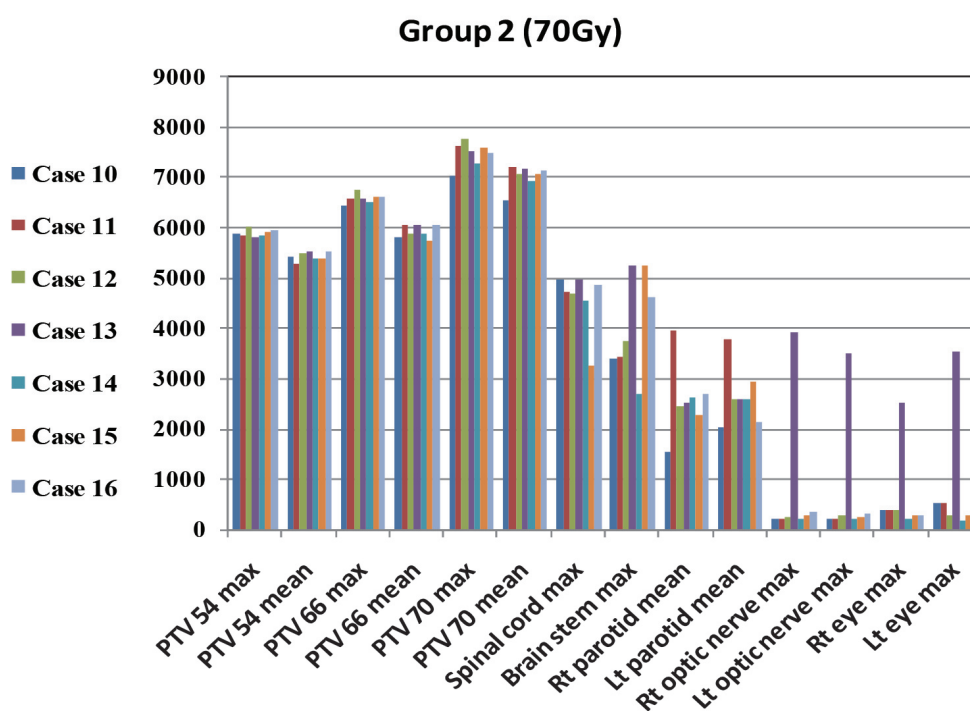
Figure 4 shows all the data for the first group (nine cases) and of figure 5 shows also all the data from the second group (seven cases). In general, aspects such as minimum dose to PTV, magnitude, localization, and extension of hot spots inside the PTV, and minimum dose to certain % of PTV volume (for example, 95% of the prescription to dose to 95% PTV) are parameters used as criteria to approve plans.

We employed the QUANTEC summary for dose (Gy), or dose/volume parameters to check plan DVHs for every case according to a well-defined acceptance criteria.¹¹ After evaluating both groups, we noticed that both right and left parotids mean doses were competing to be below

26Gy depending on their volumes; this requires more careful planning so as not to exceed its tolerance dose as in cases 2, 11, and 15 because a significantly high dose was noticed in these cases due to the large size of parotid glands; we could also conform dose and reduce the right or left parotid mean dose using MLCs or varying weight of fields with an accepted dose distribution.

From the overall evaluation of the two groups (16 cases), we achieved an accepted dose distribution for PTVs and dose to OARs in the accepted ranges with success percentage of nearly 81.13% to achieve our goal simulating inverse planning and IMRT dose distribution for accurate treatment with saving more time. Moreover, figure 6 shows a plan sum dose volume histogram (DVH) for one accepted plan for an evaluated head and neck case as an example.

We have to check these plans prior to treatment

**Figure 5.** This figure shows group (2) planning data for PTV54, PTV66, PTV70 and doses of OARs.

by means of in-vivo dosimetry (Portal Dosimetry or diodes and thermoluminescent dosimeter), which properly verifies the ability of the treatment unit to deliver the treatment according to plan.^{12,13} Portal Dosimetry is an efficient and accurate tool for verifying the delivering the treatment according to plan; however, it does not specify whether the plan provides the desired dose distribution.¹⁴

Using such a mono-isocentric plan, we achieved maximum PTV coverage, while minimum OARs exposure. MLC careful shaping for each field opening and defined weights can serve as manual 3DCRT plan optimization to gain dose distribution such as that gained from IMRT plans for different kinds of cases (head and neck or even prostate).^{9, 10} For an IMRT field comprised of several subfields, this could potentially entail much larger errors; therefore, this 3-DCRT method should be employed carefully with perfect immobilization to save time and money for patients.

Conclusion

We could achieve perfect uniform dose distribution for PTVs up to 70Gy, while sparing critical organs, including spinal cord, brainstem,

eyes, optic nerves, and parotid glands using this technique with the same gantry angles as a template plan. This template plan could serve as a flexible platform for physicists, particularly in low-and middle-income countries with limited resources and no access to inverse IMRT planning machines. Owing to the high precision and immobilization ability and stable fixation systems, the other surrounding normal tissues receive minimum doses of radiation; therefore, they are able to regenerate faster with fewer damages than tumor cells.

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Conflict of Interest

None declared.

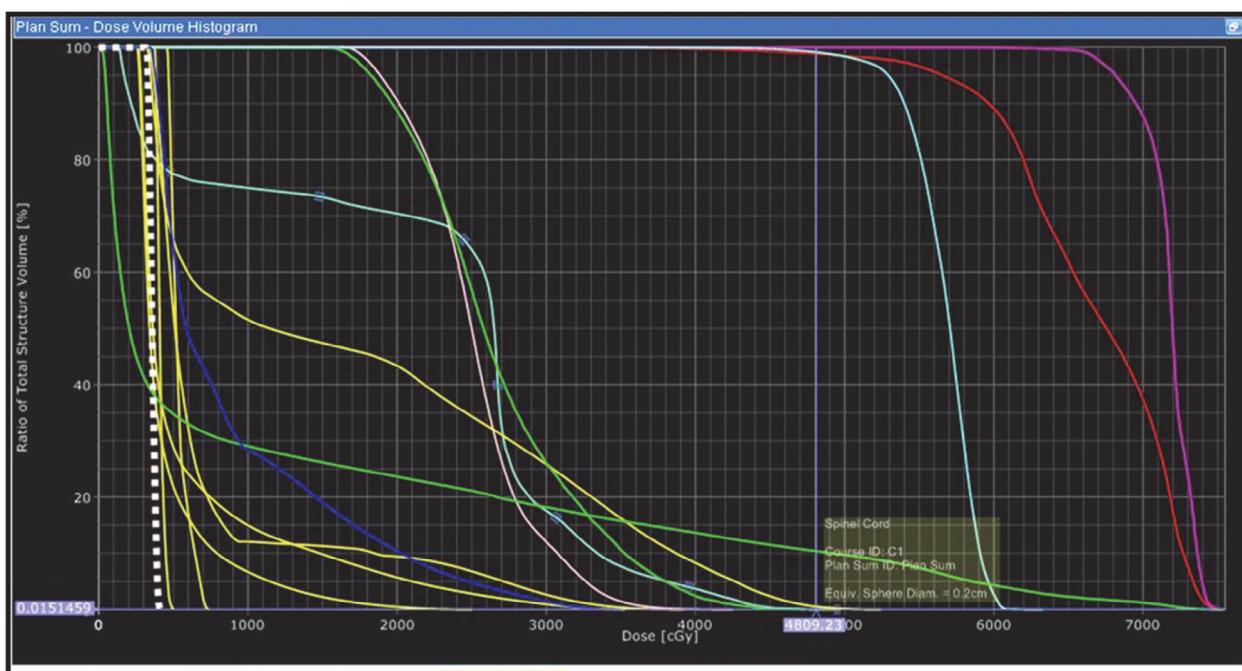


Figure 6. This figure shows DVH example for the accepted plan including delineated PTVs and OARs.

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