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A case study of IMRT planning (Plan B) subsequent to a previously treated IMRT plan (Plan A)

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Abstract

Background and purpose: Treatment of the contralateral neck after previous ipsilateral intensity modulated radiation therapy (IMRT) for head and neck cancer is a challenging problem. We have developed a technique that limits the cumulative dose to the spinal cord and brainstem while maximizing coverage of a planning target volume (PTV) in the contralateral neck. Our case involves a patient with right tonsil carcinoma who was given ipsilateral IMRT with 70Gy in 35 fractions (Plan A). A left neck recurrence was detected 14 months later. The patient underwent a neck dissection followed by postoperative left neck radiation to a dose of 66 Gy in 33 fractions (Plan B).

Materials and Methods: The spinal cord-brainstem margin (SCBM) was defined as the spinal cord and brainstem with a 1.0 cm margin. Plan A was recalculated on the postoperative CT scan but the fluence outside of SCBM was deleted. A further modification of Plan A resulted in a base plan that was summed with Plan B to evaluate the cumulative dose received by the spinal cord and brainstem. Plan B alone was used to evaluate for coverage of the contralateral neck PTV.

Results: The maximum cumulative doses to the spinal cord with 0.5cm margin and brainstem with 0.5cm margin were 51.96 Gy and 45.60 Gy respectively. For Plan B, 100% of the prescribed dose covered 95% of PTVb1.

Conclusion: The use of a modified ipsilateral IMRT plan as a base plan is an effective way to limit the cumulative dose to the spinal cord and brainstem while enabling coverage of a PTV in the contralateral neck.

1. Introduction

Intensity Modulated Radiation Therapy (IMRT) is often used for planning head and neck (H&N) cancers due to its ability to deliver a highly conformal dose distribution to a target while limiting dose to nearby critical structures such as spinal cord, brainstem, parotid gland and optic chiasm. The use of conventional 3D planning techniques for either a newly diagnosed or recurrent tumour would result in greater doses being delivered to normal tissues (1,2,3). The challenge of irradiation of the contralateral neck for recurrent disease is to respect the tissue tolerance of critical structures such as spinal cord and brainstem while adequately covering a new PTV.



The Eclipse™ planning system from Varian (Varian Medical Systems Inc., Palo Alto, CA) enables IMRT optimization to be performed by summing a previous base plan with a subsequent plan. This allows one to account for the effects of previous radiation when planning a retreatment.

At our cancer centre, we have developed a technique that sufficiently limits the cumulative dose delivered to the spinal cord and brainstem while enabling coverage of a new PTV.

2. Materials and Methods

2.1. Patient Information

A patient was given ipsilateral radiation treatment with 70Gy to PTVa1 and 56Gy to PTVa2 in 35 fractions for right tonsil carcinoma. A left neck recurrence was detected 14 months later. The patient underwent a neck dissection showing 1/54 nodes positive for carcinoma. The tumour deposit was 3 cm in size with extra nodal extension and a close margin. Postoperative left neck radiation was then given to a dose of 66 Gy to PTVb1 and 54Gy to PTVb2 in 33 fractions.

2.2. CT Simulation

CT data sets were obtained from a Phillips™ (Philips Healthcare, 3000 Minuteman Road, Andover, MA) Brilliance Big Bore scanner using 3mm slices with the patient in a supine position and immobilized using a headrest, Type-S™ thermoplastic S-Frame head shell, Type-S™ head extension and Vac-lock bag from CIVCO™ (1401 8th Street SE, Orange City, Iowa 51041).

2.3. Contouring

A Radiation Oncologist (RO) contoured the gross target volume (GTV) for the initial tumor. A PTV (70 Gy) was generated by expanding the GTV contour with a 10 mm margin in all directions except for bony interfaces. A PTV (56 Gy) was contoured for nodal regions at risk for subclinical disease. After the neck dissection for recurrent disease, a postoperative plan was generated. A PTV (66 Gy) was contoured for the recurrent tumour bed while a PTV (54 Gy) was contoured for nodal regions at risk for subclinical disease. All healthy organs including central nervous system (CNS) organs were contoured by a Radiation Therapist (RT) and verified by the RO.

2.4. Planning

The Eclipse™ treatment planning system (version 10.1.20) was used for treatment planning. A seven field IMRT plan (Plan A) with sliding window multileaf collimator (MLC) was used. The beam angles were 25°, 180°, 215°, 245°, 285°, 310° and 340°. There were no collimator rotations and no couch rotations for any of the seven beams. Fig.1(A) shows the seven beam arrangements. 99.01% of PTVa1 and 97.85% PTVa2 were covered by 100% of the prescribed doses with the maximum dose being 107.4% of the prescribed dose. The maximum doses received by spinal cord with 0.5cm margin and brainstem with 0.5cm margin were 46.70 Gy and 41.31 Gy respectively. The 0.5cm margin is the standard margin for the PRV used at our centre. It is also the recommended margin used to account for interfraction patient and organ motion in the NCIC CTG HN.6 protocol [4].

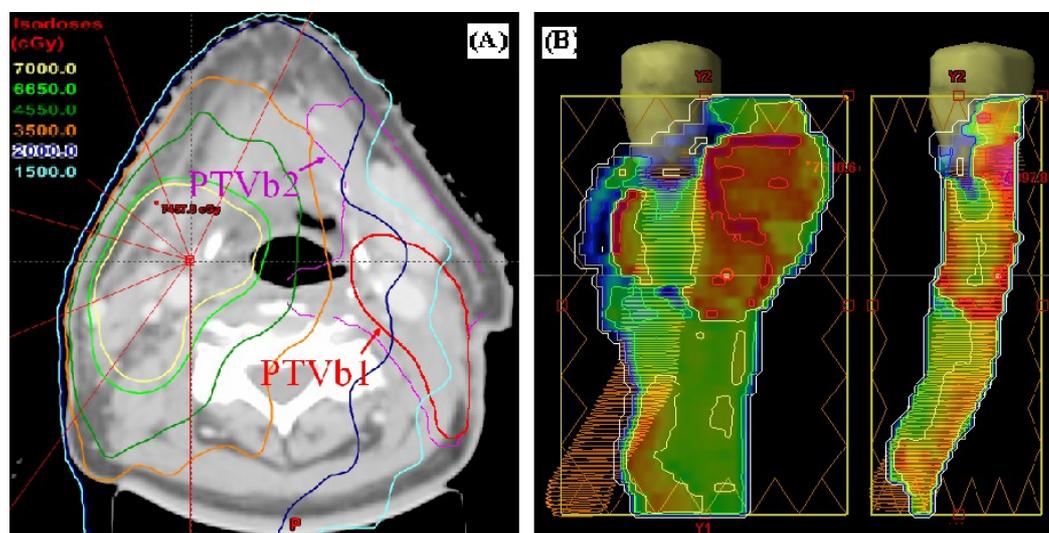


Fig.1 (A) 70 Gy in 35 fractions was given for gross disease. The 7 red lines indicate the entry directions of the 7 IMRT beams. After neck dissection for recurrent disease, 66 Gy was given to PTVb1 (in red) for the nodal bed and 54 Gy was given to PTVb2 (in purple) for possible subclinical disease in 33 fractions. (B) Beam's eye view showing one of the seven beam's fluence from plan A before (left) and after (right) the fluence outside SCBM was deleted.*

A structure named SCBM was defined as the spinal cord and brainstem with a 1.0 cm margin. Plan A was recalculated on the postoperative CT scan and this was named Plan A*. The fluence outside of SCBM from Plan A* was deleted and this modified plan was called Plan A**. Plan A** was then used as a base plan to generate the final plan (Plan B) with beam angle of 25°, 50°, 115°, 145°, 180°, 335° that treated the PTVs in the postoperative neck.

2.5. Plan evaluation

The total cumulative dose received by the spinal cord and brainstem from the summation of Plan A* and Plan B were evaluated. The isodose coverage of PTVb1 and PTVb2 was evaluated using Plan B alone.

3. Results

The maximum cumulative doses from the summation of Plan A* and Plan B to the spinal cord with 0.5cm margin and brainstem with 0.5cm margin were 51.96 Gy and 45.60 Gy respectively. 95% of PTVb1 and 81.84% of PTVb2 were covered by 100% of the prescribed doses. 89.98% of the PTVb2 volume was covered by the 95% of the prescribed dose. Since PTVb2 was a complex target spanning the entire contralateral neck, this degree of coverage was deemed acceptable by the RO. The maximum dose from Plan B alone was 112.4%.

4. Discussion

Spinal cord and brainstem toxicity are major concerns when reirradiation of the head and neck is contemplated. Various approaches have been taken to account for previous irradiation. Some centres assume that irradiated CNS tissues will recover by 50% of the dose received if there is an interval of more than one year from the initial treatment (1, 2). Other centres assume no recovery and simply add the physical doses of the initial and subsequent treatment courses when considering tissue tolerances (3). At our centre, we have taken the latter, more conservative approach.

To keep the dose to CNS structures as low as possible, our centre's policy is to avoid using beams that enter CNS structures before reaching the PTV regardless if the plan is an initial one or a

retreatment. This approach is illustrated in Fig.1. For patients receiving ipsilateral irradiation, we have designed standardized beam arrangements to facilitate this policy. For a given case, the dosimetrist will load the standardized template to see if the beam arrangement is suitable or not. The beam and collimator angles can be adjusted as needed for each case. The standard beam angles for left sided tumours are 25°, 180°, 215°, 245°, 285°, 310° and 340°. The standard beam angles for right sided tumours are 25°, 50°, 75°, 115°, 145°, 180° and 335°. For most ipsilateral tumours, the standard beam angles do not need to be changed.

At our centre, we have adopted dose constraints outlined in the National Cancer Institute of Canada Clinical Trials Group head and neck clinical protocol (NCIC CTG HN.6)(4). Dose constraints for the spinal cord with 0.5cm margin and brainstem with 0.5cm margin are 52 Gy and 60 Gy respectively. Assuming these structures received a tolerance dose from an initial treatment and that the spinal cord and brainstem recover by 50% of the dose, the dose constraints for re-irradiation would be 28.65 Gy and 39.35 Gy respectively. Although such constraints could be met in some cases, they would not be met in other situations and there remains uncertainty about the validity and amount of dose recovery. For these reasons, we felt that it would be better to have a technique that does not rely on somewhat arbitrary assumptions of dose recovery.

For the case presented above, the maximum dose to the spinal cord with 0.5cm margin was 46.70 Gy from Plan A. Without using a base plan, we would not know the precise location of this maximum dose relative to the new PTVs in the contralateral neck. In order to limit the cumulative dose to the spinal cord with 0.5 cm margin to 52 Gy we would need to give no more than 5.3 Gy to this entire region. The shortest distance between the PTVb2 (54 Gy) and the spinal cord with 0.5 cm margin is about 1 cm. A dose fall-off gradient of 9.0% per millimetre would be required to meet the spinal cord with 0.5 cm margin constraint. As a “rule of thumb”, however, the maximum dose fall-off gradient should be less than 7% per millimetre for an IMRT plan. If the dose gradient is greater than the 7% per millimetre, PTV dose conformity and homogeneity tends to be compromised.

The simplest approach for planning treatment of the contralateral neck is to recalculate Plan A on the postoperative scan without any modifications. Assuming that there has been no significant change in the size and shape of the neck, this approach would account for the entire dose previously delivered to the neck. The problem, however, is that such an approach would limit the dose one could deliver to the regions at risk in the contralateral neck since some dose would have been delivered there from the initial ipsilateral treatment. Our compromise solution is to delete the fluence outside of SCBM and use this as our base plan. This allows us to fully account for the dose previously delivered to the spinal cord and brainstem while not limiting our ability to deliver an adequate dose to the PTVs in the postoperative neck.

The selection of the margin used for SCBM was made after several analyses. If no margins were chosen on the spinal cord and brainstem, the dose to these structures would be underestimated because the effects of scatter would be ignored. Conversely, if too large of a margin were chosen, you would approach using Plan A* without any modification. Our choice of a 1.0 cm margin for SCBM was felt to be a suitable compromise.

Although Plan A** substantially reduces the dose in the contralateral neck the effects of exit dose through the spinal cord and brainstem into the contralateral neck cannot be deleted by Eclipse. We have adjusted the dose constraints to account for this issue as follows. First, the mean doses in the postoperative PTVs were calculated for Plan A**. These doses were then added to all of the optimization constraints so we could have “room” to deliver the equivalent of the exit dose discussed above. Finally, Plan A** with the adjusted optimization constraints was used as a base plan to generate Plan B.

5. Conclusion

We have developed a novel planning technique for treatment of a contralateral neck recurrence after previous ipsilateral irradiation. The original IMRT plan is recalculated on the CT scan done after the recurrence. Modifications are then made to the plan so it can be used as base plan. This allows us to

account for the cumulative dose delivered to the spinal cord and brainstem while enabling coverage of new PTVs in the contralateral neck.

6. References

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