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Setup uncertainties and PTV margins at different anatomical levels in intensity modulated radiotherapy for nasopharyngeal cancer

Milan Anjanappa[a], *Malu Rafi*[a,*], *Saju Bhasi*[b], *Rejnish Kumar*[a], *Kainickal Cessal Thommachan*[a], *Tapesh Bhattacharya*[a], *Kunnambath Ramadas*[a]

[a] *Division of Radiation Oncology, Regional Cancer Centre, Thiruvananthapuram, Kerala, India*
[b] *Division of Radiation Physics, Regional Cancer Centre, Thiruvananthapuram, Kerala, India*

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ABSTRACT

Aim: To determine the systematic error ($\sum$), random error (σ) and derive PTV margin at different levels of the target volumes in Nasopharyngeal Cancer (NPC).

Materials and methods: A retrospective offline review was done for patients who underwent IMRT for NPC from June 2015 to May 2016 at our institution.

Alternate day kV images were matched with digitally reconstructed radiographs to know the setup errors. All radiographs were matched at three levels – the clivus, third cervical (C3) and sixth cervical (C6) vertebra. The shifts in positions along the vertical, longitudinal and lateral axes were noted and the $\sum$ and σ at three levels were calculated. PTV margins were derived using van Herk's formula.

Results: Twenty patients and 300 pairs of orthogonal portal films were reviewed. The $\sum$ for the clivus, C3 and C6 along vertical, longitudinal and lateral directions were 1.6 vs. 1.8 vs. 2 mm; 1.2 vs. 1.4 vs. 1.4 mm and 0.9 vs. 1.6 and 2.3 mm, respectively. Similarly, the random errors were 1.1 vs. 1.4 vs. 1.8 mm; 1.1 vs. 1.2 vs. 1.2 mm and 1.2 vs. 1.3 vs. 1.6 mm. The PTV margin at the clivus was 4.4 mm along the vertical, 4 mm along the longitudinal direction and 3.2 m in the lateral direction. At the C3 level, it was 5.5 mm in the vertical, 5 mm in the lateral direction and 4.4 mm in the longitudinal direction. At the C6 level, it was 6.4 mm in the vertical, 6.9 mm in the lateral direction and 4.4 mm in the longitudinal direction.

Conclusion: A differential margin along different levels of target may be necessary to adequately cover the target.

* *Corresponding author at*: Division of Radiation Oncology, Regional Cancer Centre, Medical College PO, Thiruvananthapuram, Kerala, India.
E-mail address: malu_rafi@yahoo.com (M. Rafi).

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1. Background

Primary radiotherapy with or without concurrent chemotherapy is an effective curative treatment for Nasopharyngeal cancers (NPC). With the advent of intensity modulated radiotherapy (IMRT), it is possible to deliver highly conformal doses to the target volumes and at the same time reduce the dose to organs at risk (OAR) thereby achieving a maximum therapeutic gain.

The target volume in NPC usually extends from the skull base to the supraclavicular fossa. The accurate delivery of highly conformal dose with steep fall off obtained with the new planning techniques requires selection of an appropriate planning target volume (PTV). Often, a uniform PTV margin is chosen for the entire target volume. However, this may not be appropriate considering the movement of the skull and neck in spite of rigid immobilization. Further, these variations are often found to be differential at various regions.[1]

The close proximity of critical organs, like brainstem, optic apparatus and cochlea, to the target volume often necessitates stringent PTV margins. The positional accuracy during each fraction of radiation is of paramount importance in both ensuring good tumor coverage and sparing OARs. It is often difficult to attain a perfect match of the treatment portal images with the digitally reconstructed radiograph (DRR) at all levels of the target volume. Therefore, matching primary target volume at the skull base receives top priority due to the location of adjacent critical structures. This can result in positional inaccuracies in lower neck which can impact the dose delivery to this region.

2. Aim

To determine the systematic error, random error and derive PTV margin at different levels of the target volumes in *NPC*.

3. Materials and methods

3.1. *Patient selection*

20 patients with *NPC* (irrespective of stage), treated using volumetric arc therapy (VMAT) technique, between June 2015 and May 2016 were included in the analysis. All patients were treated using simultaneous integrated boost (SIB) protocol delivering 66, 60 and 54 Gy in 30 fractions to the corresponding PTVs with or without concurrent chemotherapy as indicated.

3.2. *Immobilization and ct simulation*

Patients were immobilized with the neck extended using a neck rest and use of a head and neck thermoplastic shell with 4 point fixation (Orfit). Planning CT was acquired on a wide bore CT scanner (GE optima) with the use of intravenous contrast and slice thickness of 2.5 mm. Laser markings were made on the shell at the time of CT simulation to be used for patient setup in the treatment machine.

3.3. *Planning, treatment setup and execution*

The clinical target volumes (CTV) was contoured on the planning CT scan. *The CTV to PTV margin in all patients was 5 mm.* IMRT plans using 6 MV photons were generated using the Eclipse© planning system version 13. Patients were set up in the treatment machine, aligning the treatment lasers to the markings on the shell. Necessary couch shifts as obtained from the planning system were then applied. Image verification using two orthogonal kilo voltage (kV) images (100 kV for anterior and 70 kV for lateral) were performed using the on-board imaging system. The imaging protocol followed at our institution includes daily image verification prior to treatment.

3.4. *Study design*

This study was planned as a retrospective offline review of the kV orthogonal images that were acquired for daily image verification. The kV images taken on alternate days were reviewed and compared with the DRR to assess the shifts at three different levels of the target volume. The three levels used for matching were the region of the clivus, third cervical vertebra (C3) and sixth cervical vertebra (C6) (Fig. 1). The corresponding shifts in positions along the vertical, longitudinal and lateral axes were collected for the data analysis.

4. Data analysis

The systematic error and random error for matched positions at the clivus, C3 and C6 were calculated separately. Systematic error for the population ($\sum$) was calculated by taking the standard deviation of the average value of individual mean setup error along the vertical, longitudinal and lateral directions, respectively.

Random error for the population (σ) was calculated by taking the root mean square value of individual standard deviations along the vertical, longitudinal and lateral directions respectively.

Further, the PTV margin for the antero-posterior direction, lateral direction and cranio-caudal direction for the levels were determined using the van Herk formula.[2]

$$\text{PTV margin} = 2.5\sum + 0.7\sigma.$$

5. Results

5.1. *Patient characteristics*

Patient characteristics are summarized in Table 1.

5.2. *Setup error*

For each patient, fifteen orthogonal pair portal images were reviewed off-line, amounting to a total of 300 image pairs for