



Dosimetric Evaluation of Auricular Contour Correction Effects on VMAT Nasopharynx Cancer Treatment

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OBJECTIVE

Computed tomography images used in radiotherapy are automatically created by Treatment Planning Systems using the patient's body contour. However, due to irregularities in the head-and-neck region, some corrections are required, especially for auricular contours. Since the beam entrances are at all angles, a change in the auricular contour may alter the beam's entry angle and distance, which may cause changes in the target volume and surrounding critical structure doses in the volumetric arc technique (VMAT). We aimed to dosimetrically compare the treatment plans created with and without correction of auricular contours on the planning images.

METHODS

The data of 19 nasopharyngeal cancer patients treated using VMAT were evaluated. The VMAT treatment plans made in the Eclipse Treatment Planning System using the same optimization values were evaluated based on the ability to meet dose-volume constraints. Using the Student's t-test and Wilcoxon signed-rank test, comparisons were made of planning doses, planning target volumes (PTV), conformity index (CI), homogeneity index (HI), and critical organs involved.

RESULTS

We found a statistically significant difference between the corrected and non-corrected plans regarding maximum dose (D_{max}), dose to 2% of PTV (D_2), CI, and HI. When evaluated in terms of normal tissue doses, especially in patients with level 2 cervical lymph node metastases, particularly for the parotid mean dose, a statistically significant increase in the planning dose was observed when the auricular contour was corrected ($p < 0.001$).

CONCLUSION

Thus, applying auricular contour correction on an individual patient basis seems appropriate, especially in the presence of target volumes with close localization.

Keywords: Auricular contour; contour correction; treatment planning.

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INTRODUCTION

Nasopharyngeal cancer is a unique carcinoma among head-and-neck cancers due to its epidemiology, histologic features, and sensitivity to radiotherapy (RT) and

chemotherapy. In the treatment of nasopharyngeal cancer, high-dose RT is the main treatment for the primary tumor and neck region due to the anatomical location of the nasopharynx, bilateral retropharyngeal lymph node involvement in the early period, and difficulty in

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accessing this area surgically.[1] However, when high doses of RT are given, risky organs such as the spinal cord, optic nerve, optic chiasm, pituitary, brain, brain stem, and important structures near the target, such as the temporomandibular joint, salivary glands, thyroid gland, larynx, and oropharyngeal mucosa are problematic in terms of late morbidity.[1–3] For RT of nasopharyngeal cancer, the field size is generally large, and high doses are applied; therefore, significant sequelae and side effects are expected to occur due to critical structures in the local environment. Conventional RT techniques applied in the past involved treatment from two mutually parallel fields. With the development of technology, innovations, and treatment advances in recent years, there has been a transition from conventional therapy to conformal therapy, intensity-modulated RT (IMRT), and volumetric arc therapy (VMAT).[4–6]

Conformal delivery of a target volume prescribed dose that minimizes the dose to normal tissues is possible with the introduction of IMRT in the discipline of RT, thereby reducing radiation-induced post-therapy complications. Even faster and more effective delivery of higher or equivalent dose distributions is possible with VMAT.[2,3]

With these developments in treatment planning techniques, inhomogeneity in the irradiated area is an important problem. For nasopharyngeal cancer treatments behind the nasal cavity, where the air passage expands, the beam often passes through an air layer before reaching the surface of the tumor. In such cases, electronic balance is not fully formed at the air-tumor intersection resulting in dose reductions in the air-tissue intersection. Many studies show that the magnitude of the dose decrease in the air-tissue interface depends on the geometry of the air gap, the volume of the space, the size of the irradiated area, and the photon energy used.[7–11] In addition, external contour changes, which are automatically transferred to the treatment planning system after computed tomography (CT) imaging and have an important place in beam entrances, can also create similar problems. When treating patients with nasopharyngeal cancer using VMAT, the gantry irradiates with 360° rotation from all angles, and the speed, field shape, and dose rate constantly change during the rotation.[12] For this reason, changes that may occur, especially in the contour of the auricle, may cause alterations in the treatment volume dose distribution and critical structure doses due to changes in beam entrance distance, angle of entry, and scattering.

The American Association of Physicists in Medicine, Task Group 176 (TG-176), recommended that

the immobilization devices be contoured considering dosimetric effects.[13] However, dosimetric effects due to the change in the volume of the body structure still need to be clarified as there are no guidelines for defining body contour. Treatment planning priorities are given in radiation therapy oncology group (RTOG) guidelines as critical normal structure limitations and target volume dose specifications for planning targets (salivary glands) and other normal structures.[14] In terms of planning objectives, the auricular region was chosen due to its proximity to the salivary glands and because it could create an external contour change effect due to the use of masks. We aimed to compare VMAT treatment plans made with and without correction of body contours (the auricle) manually in all sections. In the final comparison, the target volume for both planning dose-volume histograms and dose criteria for critical organs were evaluated.

MATERIALS AND METHODS

Patient Characteristics

This study included 19 patients treated for nasopharynx cancer at our institution. Four patients had stage 2 disease (21%), seven had Stage 3 disease (37%), and eight had Stage 4 disease (42%). We selected patients treated with IMRT using the VMAT technique and performed a retrospective analysis with the appropriate Local Ethics Committee approval A-46 on January 07, 2021.

Imaging and Contouring

A thermoplastic head and shoulder mask were used to immobilize patients in the supine position. The planning CT was achieved with a 2.5 mm slice thickness from the head to the carina on a Discovery RT scanner (GE Healthcare, WI, and USA). The RT planning CT for detected primary tumors and metastatic lymph nodes was fused with positron emission tomography-CT and magnetic resonance images. Organs at risk (OAR) and target volumes were contoured according to RTOG guidelines. Gross tumor volume (GTV) of the primary tumor and metastatic lymph nodes were defined according to clinical and radiological findings. The following three clinical target volumes (CTV) were delineated: CTV 66–70 Gy covered the primary tumor and metastatic lymph node and was defined by adding 5 mm to the GTV, CTV 60 Gy included both the whole nasopharynx and the whole involved nodal level, and CTV 54 Gy covered high-risk regions and elective bilateral cer-

vical lymph nodes. Planning target volume (PTV) was defined by adding 3 mm in all directions for all CTV. For nasopharyngeal carcinoma, OAR included the optic chiasm, optic nerves, oral cavity, brain stem, cochlea, temporomandibular junction, parotid gland, spinal cord, and muscles of the pharynx.

Treatment Planning and Data Analysis

The structures for all patients were identical except for the external contour. The same physicist automatically generated two structure sets with two body structures with a value of -350 Hounsfield Unit (HU) for all patients. Auricular correction (Ext-a) values were made manually slice-by-slice, while the other values (Ext-b) used the automatically created contour. The dose distributions with Ext-a CT were then calculated using identical VMAT plans and optimization as those generated with Ext-b CT and the same optimization process in the Treatment Planning System using an Eclipse version 10.0 progressive resolution optimizer (Varian Medical System, Palo Alto, CA, USA).

Each VMAT plan generated two full arcs with energy of 6 MV. The simultaneous integrated boost technique was used with three target volumes. For the calculation of dose distributions, the anisotropic analytic algorithm was used. The dose calculation grid was 2 mm. The median dose of RT was 70 Gy (range 66–70 Gy) in 33 fractions. All treatments were delivered using a RapidArc linear accelerator (Varian Medical System, Palo Alto, CA, USA). The RT volume verification for image-guided RT was conducted with cone-beam CT or kV for each fraction. Dosimetric comparisons for maximum dose (D_{max}), dose to 95% of the target volume ($D_{95\%}$), and dose to 2% of the target volume (D_2) for each target volume were performed for all plans. The homogeneity index (HI) and conformity index (CI) were also calculated.

The maximum and mean dose to each parotid gland and cochlea were evaluated due to their proximity to the auricle.

In addition, the time from the start to the end of auricular contouring was recorded for each patient plan to determine the additional workload when manual contouring was added to the planning.

Statistical Analysis

The computer software SPSS version 21 for Windows (IBM Corp. Armonk, NY, USA) was used for all statistical analyses. The statistical significance of the differences was analyzed using the paired t-test and Wilcoxon signed-rank test. Significance was considered at $p < 0.05$ level.

Table 1 Target volume dosimetric comparisons

Parameters	Ext-a corrected		Ext-b non-corrected		p
	Mean	SD	Mean	SD	
HI	0.06	0.023	0.15	0.227	<0.001
CI	1.25	0.180	1.23	0.181	0.037
Max. dose (%)	105.00	1.215	106.35	2.017	0.002
$D_{95\%}$	97.06	1.296	96.62	1.320	0.068
D_2	102.94	0.887	103.71	1.208	0.001

HI (homogeneity index) is defined as $HI = (D_{2\%} - D_{98\%}) / \text{mean dose}$, where $D_{2\%}$ and $D_{98\%}$ were the maximum and minimum doses at 2% and 98% of the PTV volume, respectively. CI (conformity index) is defined as $CI = V_{PIV} / V_{TV}$, where TV is the target volume, and PIV is the prescription isodose volume that completely envelops the tumor volume. SD: standard deviation; Max. Dose: Maximum dose; PTV: Planning target volumes; V: Volume; PIV: Prescription isodose volume; TV: Target volume

Table 2 Dosimetric comparisons in organs at risk

Organ doses	Ext-a corrected		Ext-b non-corrected		p
	Mean	SD	Mean	SD	
Parotid R max	97.29	12.274	95.94	15.923	0.475
Parotid L max	92.54	16.119	90.89	17.458	0.400
Parotid R mean	45.81	17.384	43.94	18.404	<0.001
Parotid L mean	36.62	10.676	35.08	9.704	0.164
Cochlea R max	71.75	18.068	70.30	20.180	0.271
Cochlea L max	65.52	18.705	63.98	20.354	0.334
Cochlea R mean	60.02	16.005	59.42	17.747	0.597
Cochlea L mean	55.45	17.964	53.89	19.043	0.256

SD: Standard deviation; R: Right; L: Left; Max: Maximum

RESULTS

Some PTV has a close relationship with critical organs such as the optic tract brainstem; therefore, RT doses were changed due to this association. The target data of the plans made in Ext-a and Ext-b are given in Table 1, and the data of critical organs are shown in Table 2. Due to the use of different dose schemes in patients, the target volume and critical structure doses are provided based on % evaluation.

Comparison of HI, CI, D_{max} , $D_{95\%}$, and D_2 showed statistically significant differences. When plans were compared, statistical significance was demonstrated between the groups for HI, CI, D_{max} , $D_{95\%}$, and D_2 . Still, since the values for both plans were acceptable, the need for auricular contour correction may vary according to the patient. Figure 1 shows the dose distribution and auricular contour for 26 Gy.

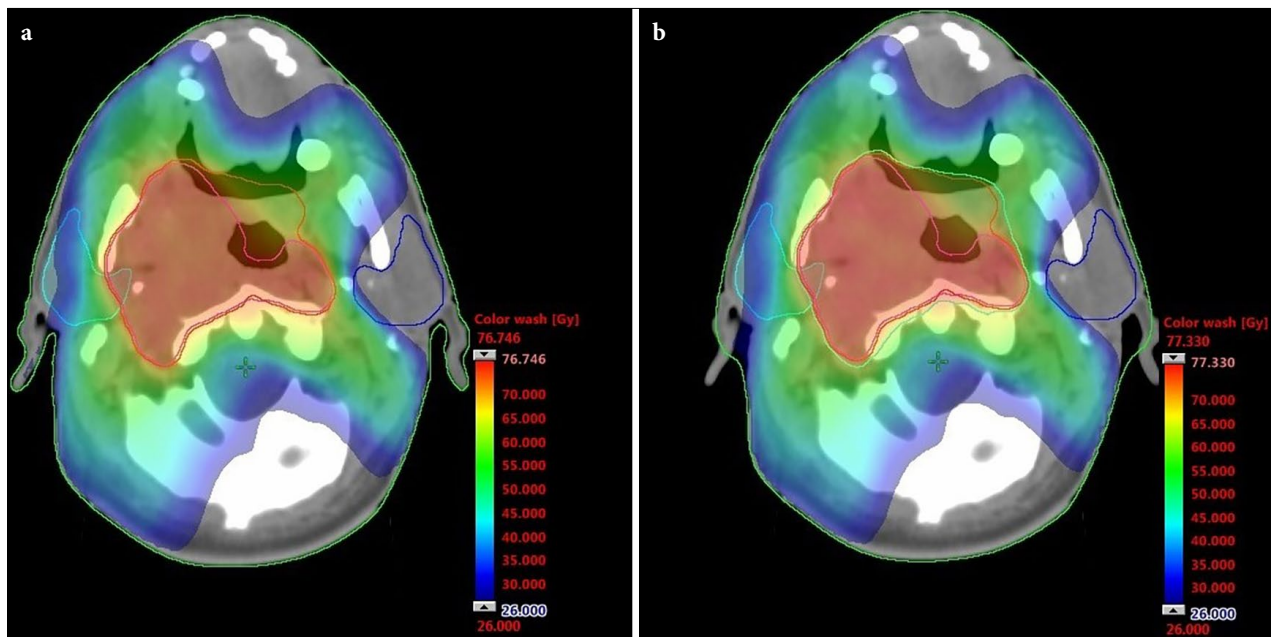


Fig. 1. Color wash dose distributions on transverse computed tomography (CT) views for (a) Ext-a (left) and (b) Ext-b (right) for a representative case. Color wash dose range: 26 Gy (blue)-70 Gy (red).

No difference was observed for cochlea when evaluated in terms of normal tissue doses. However, a statistically significant increase in parotid mean dose was observed, especially in patients with level 2 cervical lymph node metastasis when the auricular contour was corrected in planning ($p < 0.001$).

The mean additional time required for the fully manual procedure in Ext-a without the use of any additional tools was 6.7 ± 1.2 min and 2.3 ± 0.3 when done with the drawing tools adaptive option on the Eclipse Treatment Planning System. For Ext-b, no additional time was spent as the Treatment Planning System automatic contour option was used.

DISCUSSION

Accurate determination of body contour in calculating RT dose distribution in treatment planning is important for precise dose calculation. There are many studies on changes in the target volume and critical organ doses caused by variations in external contour due to reasons such as weight loss during treatment. When Wang et al.[15] compared the second plan after the 18th fraction in 15 patients with nasopharyngeal cancer and the initial treatment plan, for the hybrid and new plan, the mean dose of the left and right parotid increased by 2.97 Gy and 2.57 Gy, respectively. They stated that anatomical changes during treatment might increase the

dose to critical organs, and replanning may benefit the patient. Loo et al.[16] investigated tumor shrinkage and contour changes that may occur during the treatment of head and neck cancers. The change in the planned and administered dose during RT for five patients was evaluated by recalculating all doses on eight megavoltage CT (MVCT) images taken daily in different weeks. As a result, the dose increased from 26.2 Gy by an average of 7.3 Gy (range 1.1–11.6 Gy) in the contralateral parotid. It was observed that the contralateral parotid dose increased an average of 19.3% (range 8.2–41.5%) in each fraction, while the ipsilateral parotid dose increased an average of 30.2% (17.1–55.8%). The investigators stated that there were significant changes in parotid volume and dose during treatment and that adaptive therapy could be helpful in evaluating this change.

Chen et al.[17] evaluated the effect of weight loss on target volume and OAR in 25 patients with nasopharyngeal cancer. They found that the dose to the brain stem and spinal cord increased in all plans by pulling the body contour change in 2, 3, and 5 mm symmetrically from all directions, and the dose to the parotid was lower than in the original plan. They explained that they did not consider the parotid gland's volumetric and positional changes for the low dose in the parotid gland.

In our study, in patients with level 2 cervical lymph node metastases whose auricular contour was corrected, the dose change in automatic contour planning was 43.94%, while it was 45.81% in corrected contour

planning ($p < 0.001$). Although within the clinical acceptance criteria in terms of other volumes, we saw a change in the way; it is given in Table 1.

Lee et al.[18] evaluated the dosimetric effect of external contour on VMAT plans at different HU values in patients with prostate and head and neck cancers. VMAT plans with 180 HU were compared with those obtained with external contours at -350 , -700 , and -980 HU values. The choice of -180 HU for the original VMAT plan was selected due to the lack of a guideline for defining body structure. In the AAPM TG-176 report, it is stated that the HU threshold value should be lower than -980 HU to incorporate immobilization devices such as thermoplastic mask, pillow, or vacuum bag into the body structure while shaping the external contour.[13] We used external contours with a predefined threshold value (-350 HU) automatically created with the Eclipse body searching tool for all patients in our clinic.

These studies are generally designed to consider patients' weight loss status or possibilities. However, during contouring at the beginning of treatment, depending on the clinical routine or the user, an external contour is usually created with automatic contouring, and no specific correction is applied to a particular area. Wu et al.[19] investigated the dose difference caused by changes in anatomy due to weight loss during RT. They evaluated the dose distribution in IMRT/VMAT treatment using different possibilities for narrowing and widening the external contour from different directions at the same rate. They stated that while body contour expansion causes coverage loss, body contour reduction increases the dose given to OAR. They noted that RT personnel could determine the necessity for re-simulation and replanning according to external contour changes. In addition to these evaluations, the need for additional manual correction, as in our study, is an issue that RT personnel should evaluate. In such cases, the planning time may be longer; however, the tools of today's contouring stations offer more practical solutions, and the processes can be completed in a shorter time.

There are no studies on the effect of automatic contour correction, especially on an inclined surface such as an auricle. Thus, our study aimed to evaluate the target volume and dose change in critical organs using different body contours.

CONCLUSION

The value of using adaptive therapy for patients for reasons such as weight loss or tumor shrinkage is inevitable. Nowadays, treatment device configurations continue to

be developed with features that allow adaptive therapy. Changes in the external contour of the patient should be considered with this technology and checked by RT personnel. It was observed that plans with and without auricle correction were dosimetrically within the clinical acceptance criteria. Still, the parotid mean dose increased in plans with contour correction, especially in patients with level 2 involvement. Although changes in other dosimetric parameters are considered clinically insignificant, it is important to minimize errors during RT to provide more accurate patient treatment.

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