Iranian Journal of Medical Physics

ijmp.mums.ac.ir

Influence of Normal Tissue Objective Tools on Treatment Planning System in Nasopharyngeal Carcinoma (NPC): A 3D Printed Anthropomorphic Phantom Study

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ARTICLE INFO

Article type:
Original Paper

Article history:
Received: Dec 16, 2023
Accepted: Apr 13, 2024

Keywords:
Evaluation Index
Parameters
IMRT
Normal Tissue Objective (NTO)
Treatment Planning System

ABSTRACT

Introduction: The normal tissue objective (NTO), one of the new aspects in the radiation treatment planning system (TPS), aims to lower the absorbed dose received by organs at risk (OARs) close to the target volume or Planning Target Volume (PTV). This study was conducted to ascertain the impact of planning in nasopharyngeal cancer (NPC) cases both with and without manual NTO settings.

Material and Methods: The study used a 3D printed head and neck phantom exposed to radiation using the Intensity Modulated Radiation Therapy (IMRT) technique with 6000 cGy prescribed dose and divided into 30 fractions to find the discrepancies between the manually calculated absorbed dose and the automatic calculated absorbed dose of TPS. Moreover, evaluation parameter indicators, including the homogeneity index (HI), conformity index (CI), gradient index (GI), and comprehensive quality index (CQI), were used to make comparisons. NTO parameter used in manual plans are f_0 = 107%, f_∞ = 65%, dose fall-off k = 0.05 mm^{-1}, and x_{start} = 0.75 cm.

Results: The statistical analysis resulted in a significant difference between the calculated absorbed dose and TPS's absorbed dose of Automatic NTO and Manual NTO, whereas, Without NTO plans, there was no statistical difference. The HI values for Automatic NTO, Manual NTO, and Without NTO are 0.118, 0.05 , and 0.053, respectively. The CI values for Automatic NTO, Manual NTO, and Without NTO are 0.91, 0.99, and 0,19. The GI value for Automatic NTO, Manual NTO, and Without NTO are 3.34, 4.94, and 7.29, respectively. CQI parameter showed that the Automatic NTO plan performs better than the Manual NTO plan based on the maximum dose received by the OAR.

Conclusion: In this study, the manual NTO plan showed better performance by reducing hot spots in the central region of PTV.

► *Please cite this article as:*
Noersjafrudin IR, Hanum UQ, Marufah AL, Putranto AMY, Endarko E. Influence of Normal Tissue Objective Tools on Treatment Planning System in Nasopharyngeal Carcinoma (NPC): A 3D Printed Anthropomorphic Phantom Study. Iran J Med Phys 2024; 21: 409-417. 10.22038/ijmp.2024.76906.2352.

Introduction

The nasopharynx is a soft plate-shaped body part resembling a tube connecting the nose and the oropharynx. Cancer that develops from this area is usually a type of squamous cell carcinoma that attacks the pharyngeal recess and is caused by the Ebstein-Barr virus (EBV) [1]. In Indonesia, cases have been recorded at an average of 6.2/100,000 with 13,000 new cases, although only a small proportion have been documented [2]. Indonesia has the largest population in Southeast Asia, with the fifth highest incidence rate of nasopharyngeal cancer among malignant neoplasms [3].

Treatment using the radiotherapy intensity modulated radiation therapy (IMRT) technique has been applied for many years due to its advantages in reducing excess dose to off-target volumes and maximizing dose distribution to target organs [4] with field settings that can adjust the shape of the target organ [5]. Conformal dose distribution allows the IMRT modality able to reduce the dose absorbed by organs at risk (OAR), such as the brainstem or spinal cord [6]. Some studies have proven that the IMRT technique is better at handling head and neck case in terms of normal tissues sparing with less toxicities [7].

Normal Tissue Objective (NTO) is a tool to reduce dose leakage by creating a concentric ring structure outside the Planning Target Volume (PTV) [8]. Planning Target Volume (PTV) refers to the volume defined in radiotherapy planning to ensure target accuracy. Caldeira et al. mentioned that using NTO successfully reduced the absorbed dose received by the OAR [9]. Eclipse's Treatment Planning System (TPS), a specialized software used in radiotherapy to design and optimize individualized treatment plans,

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has been developing a novel constraining tool, namely Normal Tissue Objective (NTO), to limit the spread of dose to normal tissue [10]. Normal Tissue Objective (NTO) refers to the parameters set during radiotherapy planning to minimize the radiation dose to healthy tissues while ensuring effective tumor treatment. Research that has been done with the implementation of NTO settings includes prostate cancer cases [9], brain tumors [11], and lung cases [12]. Research on prostate, lung, and brain cancer cases shows that Manual NTO improves hotspot centralization in PTV and provides better conformity, as indicated by the conformity index value [[12][13][14]]. To date, no studies have explored the effect of NTO on nasopharyngeal cancer cases with IMRT techniques.

The implementation of NTO settings has been recorded in several journals, but no one has yet investigated the effect of automatic and manual NTO variations in cases of nasopharyngeal cancer with IMRT modality. This study focused on finding the effect of NTO on a patient-absorbed dose by comparing evaluation parameter indices such as homogeneity index (HI), conformity index (CI), conventional gradient index (GI), and comprehensive quality index (CQI) to evaluate absorbed dose against normal tissue. A dose-volume histogram (DVH) analysis was also performed to determine the maximum dose received by the OAR.

Materials and Methods

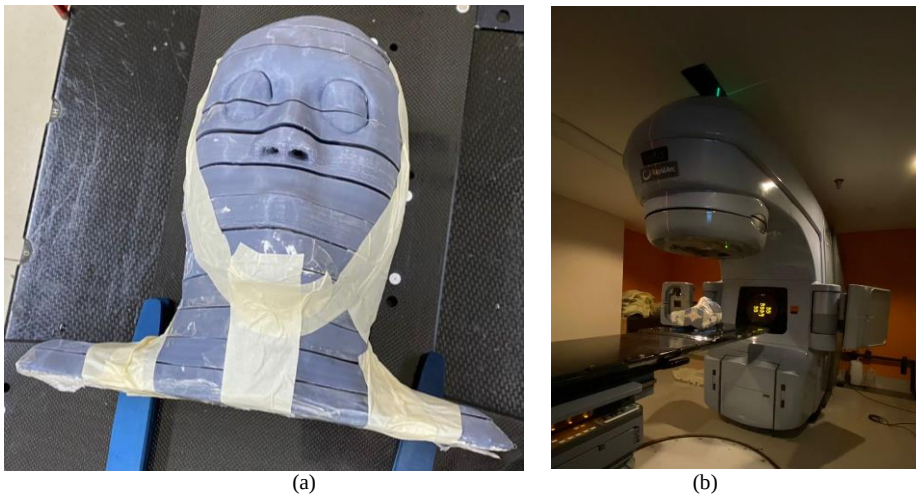
This study used a specific head-neck phantom as shown in Figure 1a as the object of study referred to the patent document P00202214766 by Endarko et al. [15]. The material used in phantom fabrication are polylactic acid as the tissue replication, gypsum as the bone substitute, lastly, the cancer nodes are made by sodium alginate solution. The detector used was GafChromic EBT3 film due to its exceptional performance in accurately measuring doses within the range up to 102 Gy [16]. This selection was made to minimize potential measurement errors during data analysis.

The tools used during the research are slab water phantom used for testing and calibration of EBT3 film, Philips CT scan type Brilliance CT Big Bore to scan the phantom model virtually, linac type Varian Clinac iX 2300 series 4740 to provide radiation exposure to the film and the phantom (Figure 1b), and Epson Expression 10000XL scanner to scan the dosimeter film that has been irradiated. The film was cut at a 3 × 2.5 cm source to surface distance (SSD) of 100 cm using a water slab phantom. The irradiation dose range used in film calibration is within the range of 0 – 450 MU (Figure 2a). Table 1–3 provides the calibration settings for the film, which we referred to for evaluation and adjustment purposes. The film analysis took place 24 hours after irradiation to enhance color variation on the film, consequently minimizing calibration uncertainty. Analysis of the film will produce an EBT3 response curve, which represents the relationship between optical density (netOD) and dose at each energy plotted on a third-order polynomial graph.

Optical density (netOD) highly depends on the absorbed dose or energy in the film. Therefore, to obtain the absorbed dose in the film, the formula applied is as follows [16]:

$$OD = -\log 10\left(\frac{I}{I_0}\right) \quad (1)$$

where I_0 is the light intensity emitted from the light source and I is the light intensity transmitted through the film [16].



(a) (b)

Figure 1. (a) The head-neck anthropomorphic phantom used for dose distribution measurement; (b) Irradiation setup of phantom

Table 1. TPS Settings for Manual NTO Variations with 7 Radiation Fields Using 6 MV Photon IMRT Technique

Field ID	Weight	SSD(cm)	Gantry (deg)	Coll(deg)	Couch(deg)	MU/fx	Jaw max aperture (cm)			
							X1 (cm)	X2 (cm)	Y1 (cm)	Y2 (cm)
Field 1	1.00	89.9	0.0	0.0	0.0	177	+13.3	+9.5	+9.8	+9.5
Field 2	1.00	92.9	51.0	0.0	0.0	164	+7.8	+11.3	+10.0	+9.3
Field 3	1.00	94.0	203.0	0.0	0.0	154	+11.3	+12.3	+10.5	+9.0
Field 4	1.00	94.3	154.0	0.0	0.0	138	+8.0	+14.0	+10.5	+9.0
Field 5	1.00	94.0	205.0	0.0	0.0	153	+11.5	+12.0	+10.5	+9.0
Field 6	1.00	92.4	257.0	0.0	0.0	124	+8.8	+7.5	+11.0	+9.3
Field 7	1.00	93.1	308.0	0.0	0.0	175	+13.0	+8.3	+10.3	+9.5
Coll: Collimator										

Table 2. TPS Settings for Automatic NTO Variations with 7 Radiation Fields Using 6 MV Photon IMRT Technique

Field ID	Weight	SSD(cm)	Gantry (deg)	Coll(deg)	Couch(deg)	MU/fx	Jaw max aperture (cm)			
							X1 (cm)	X2 (cm)	Y1 (cm)	Y2 (cm)
Field 1	1.00	89.9	0.0	0.0	0.0	201	+13.3	+9.5	+9.8	+9.5
Field 2	1.00	92.9	51.0	0.0	0.0	186	+7.7	+11.3	+10.0	+9.3
Field 3	1.00	94.0	203.0	0.0	0.0	164	+11.3	+12.3	+10.5	+9.0
Field 4	1.00	94.3	154.0	0.0	0.0	155	+8.0	+12.2	+10.5	+9.0
Field 5	1.00	94.0	205.0	0.0	0.0	156	+11.3	+12.0	+10.5	+9.0
Field 6	1.00	92.4	257.0	0.0	0.0	156	+8.0	+7.3	+11.0	+9.3
Field 7	1.00	93.1	308.0	0.0	0.0	139	+7.3	+8.3	+10.3	+9.5
Coll: Collimator										

Table 3. TPS Settings for Variations Without NTO with 7 Radiation Fields Using 6 MV Photon IMRT Technique

Field ID	Weight	SSD(cm)	Gantry (deg)	Coll(deg)	Couch(deg)	MU/fx	Jaw max aperture (cm)			
							X1 (cm)	X2 (cm)	Y1 (cm)	Y2 (cm)
Field 1	1.00	94.0	0.0	0.0	0.0	59	+13.3	+9.5	+9.8	+9.5
Field 2	1.00	93.8	51.0	0.0	0.0	86	+7.7	+11.3	+10.0	+9.3
Field 3	1.00	93.1	203.0	0.0	0.0	75	+11.3	+12.3	+10.5	+9.0
Field 4	1.00	89.9	154.0	0.0	0.0	79	+8.0	+12.2	+10.5	+9.0
Field 5	1.00	92.9	205.0	0.0	0.0	108	+11.3	+12.0	+10.5	+9.0
Field 6	1.00	94.3	257.0	0.0	0.0	82	+8.0	+7.3	+11.0	+9.3
Field 7	1.00	94.3	308.0	0.0	0.0	89	+7.3	+8.3	+10.3	+9.5
Coll: Collimator										

For the planning construction using Eclipse TPS, seven fields were utilized with the IMRT technique using gantry arcs 0, 51, 203, 154, 205, 257, and 308° [11]. The dose constraints used were based on QUANTEC and CORSAIR [14], which are eye (D_{max} < 45 Gy), brain (D_{max} < 72 Gy), brainstem (D_{max} < 54 Gy and V1 < 60 Gy), spinal cord (Dmax < 50 Gy), and parotid gland (V30 Gy < 50%). The prescribed dose was 60 Gy with a fraction dose of 2 Gy. The NTO setting priority was set at 150 with manually set parameters, stated as f_0 = 107%, $f\infty$ = 65%, fall-off dose coefficient k = 0.05 mm^{-1}, and x_{start} = 0.75 cm (Figure 3a). PTV and OARs are manually contoured, as shown in Figure 3b. All IMRT planning of phantom was irradiated using a Varian 6 MV (Varian Clinac iX; linear accelerator, USA). Treatment planning was considered optimal when the prescription dose covered at least 95% of the target volume and the maximum dose did not exceed 107% of the prescription dose in accordance with ICRU 83.

NTO is based on an exponential function defined by the parameters given in equation 1 [12]:

$$f(r) = f_0 e^{-k(r-r_s)} + f_\infty \left(1 - e^{-k(r-r_s)}\right), \quad r \geq r_s$$
$$f(r) = f_o, \quad r < r_s \qquad (2)$$

where r_s is the initial distance from the PTV edge (cm), r is the distance to r_s (cm), f_0 is the initial dose (%), f_∞ is the final dose, and k is the dose decay constant [12].

Each plan is evaluated using parameter indices obtained from DVH. The indices are HI, CI, and GI, which represent the uniformity of the dose received by the PTV characterized by homogeneity close to 0, the coverage of the radiation dose received by the PTV characterized by conformity values close to 1, and the steepness of the dose fall-off outside the PTV. In addition to CI, HI, and GI, a new evaluation index parameter called the comprehensive quality index (CQI) is used to compare the two plans. The research used the CQI index to compare plans with Automatic NTO and Manual NTO plans.

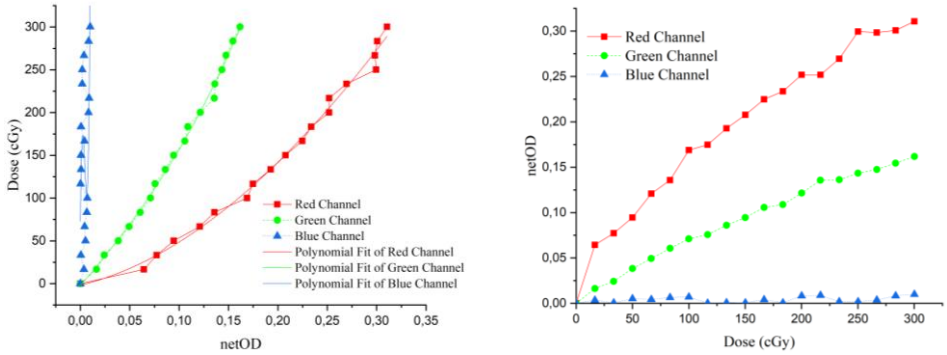
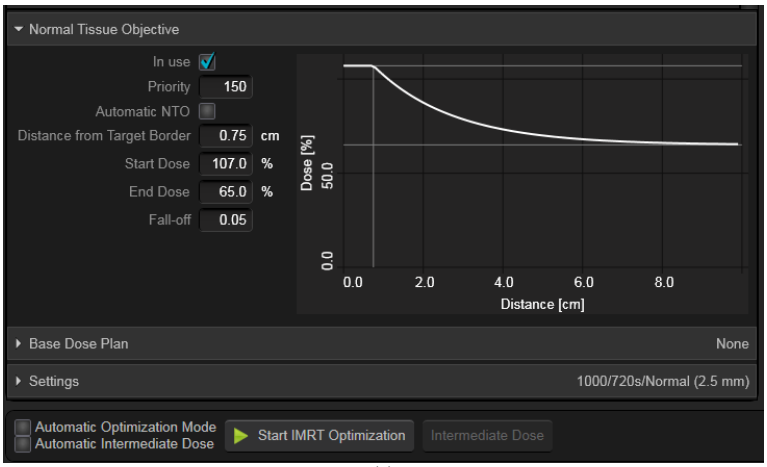
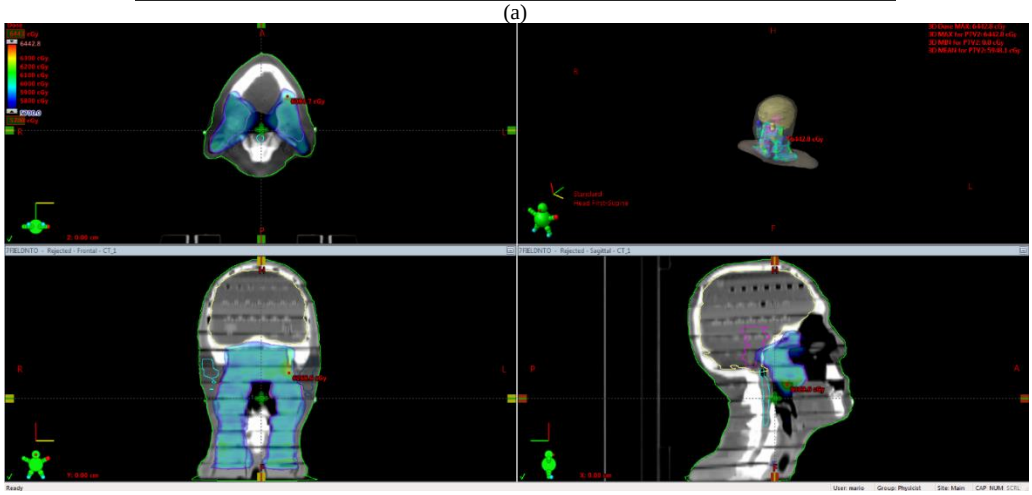


Figure 2. (a) Irradiated films used in film calibration; (b) Calibration curve analyzed in red, green, and blue channel; (c) Sensitometry graph of GAFChromic EBT3.



(a)



(b)

Figure 3. (a) Interface of Eclipse's Normal Tissue Objective (NTO) settings in NTO Manual with priority set to 150; (b) Treatment planning dose distribution of Nasopharyngeal cancer (NPC) case

The formulation of HI, CI, GI, and CQI calculations uses the equation 2 [17]:

$$HI = \frac{D_2 - D_{98}}{D_{50}} \quad (3)$$

where D_2 represents the minimum dose received at 2% of the target volume, and D_{98} represents the maximum dose received at 98% of the target volume. The ideal value is 0 and will increase as the planning becomes more inhomogeneous [17]:

$$CI = \frac{V_{95}}{TV_{PTV}} \quad (4)$$

where V_{95} represents the volume covered by 95% of the dose and TV is the total volume of the PTV target. CI equal to 1 is the ideal value. A value close to CI indicates that the total target volume covers the irradiated target volume [17]:

$$GI = \frac{V_{50}}{V_{100}} \quad (5)$$

where V_{50} is the volume receiving 50% of the total prescription dose and V_{100} is the volume receiving 100% of the total dose [17]. GI expresses the off-target dose fall-off, which is the distance between the region of targeted high-dose radiation and the therapeutic field [10].

$$CQI = \frac{1}{N}\sum_{i=1}^{N}\frac{\left(D_{1\%}^{NTOManual}\right)_i}{\left(D_{1\%}^{NTOAuto}\right)_i} \quad [10]$$

where i is the index of each OAR in the planning. $D_{1\%}^{NTOmanual}$ is the maximum dose to each OAR in Manual NTO planning and $D_{1\%}^{NTOAuto}$ is the maximum dose to the OAR in Automatic NTO planning. A CQI value less than 1 indicates that using Manual NTO can protect the OAR better than planning with Automatic NTO [10].

Verification of the calculated absorbed dose in the phantom was used to determine the uncertainty of the dose received by PTV and organs between EBT3 (calculated dose) and the dose predicted by TPS [19].

$$\%\Delta D = \left(\frac{D_{meaured} - D_{Planned}}{D_{Planned}}\right)\times 100 \quad (7)$$

where $D_{measured}$ is the measured absorbed dose and $D_{planned}$ is the absorbed dose at TPS that the system automatically computed[19]. The film was scanned with an image type of 48 bits and a spatial resolution of 720 dpi. Film analysis was performed with calibration curves in the RGB channel, as shown in Figure 2a-b.

In addition, Mann–Whitney U tests were conducted to determine whether differences in dose absorbed levels achieved between every plan were statistically significant.

Results

DVH Analysis

This study's main objective is to ascertain the impact of planning in nasopharyngeal cancer (NPC) cases, both with and without manual NTO settings. Evaluating TPS could be done by observing DVH, as shown in Figure 4. The DVH contains the prescribed dose delivered at the PTV and visualizes the radiation dose hitting the OAR around the PTV.

Based on Table 1, the target volume at D_{98} in Automatic NTO planning does not satisfy the ICRU protocol recommendations because the volume covered by 98% of the prescription dose is only 93.02% of the total volume even though the maximum dose of this Automatic NTO is in accordance with ICRU 83 protocol. The Manual NTO and Without NTO are in accordance with ICRU 83, with target volumes for minimum and maximum doses already providing PTV coverage.

Plan Evaluation Indices

Various studies confirmed that using plan evaluation indices as a dose quantification analysis represents the quality of therapy. Table 4 shows the calculation results of plan evaluation indices (HI, CI, and GI). Plans with HI value closest to the ideal are Manual and Without NTO plans. Meanwhile, the plan with the best CI value close to 1 is the Manual NTO plan. The plan with the worst GI value is the Without NTO plan. CQI compares automatic and manual NTO regarding the maximum dose absorbed by each OAR. However, the Manual NTO plan failed to show any improvement in reducing the maximum dose received by the OARs, except for the right and left eyes.

Verification of Absorbed Dose in OAR

Dose verification is meant to determine whether the radiation dose emitted by the linac is in conformance with the dose profile of the TPS. The protocol standard is based on Technical Report Series (TRS) 398 [20]. This protocol recommends that the radiation dose received by the patient is within the error tolerance range of 0 – 5%, with at least the absorbed dose corresponding to an uncertainty of 2.5% in the standard deviation calculation. The ±5% discrepancy uncertainty describes the tolerance between the prescribed and delivered doses at the target volume.

Table 1. Details of the minimum and maximum doses at Planning Target Volume (PTV) based on ICRU 83 in all plans.

Plans	D_{98} PTV		D_2 PTV	
	Dose (cGy)	Volume (%)	Dose (cGy)	Volume (%)
Automatic NTO	5590.8	93.18%	6291.3	104.85%
Manual NTO	5854.5	97.58%	6182.7	103.05%
Without NTO	5856.0	97.60%	6126.0	102.10%

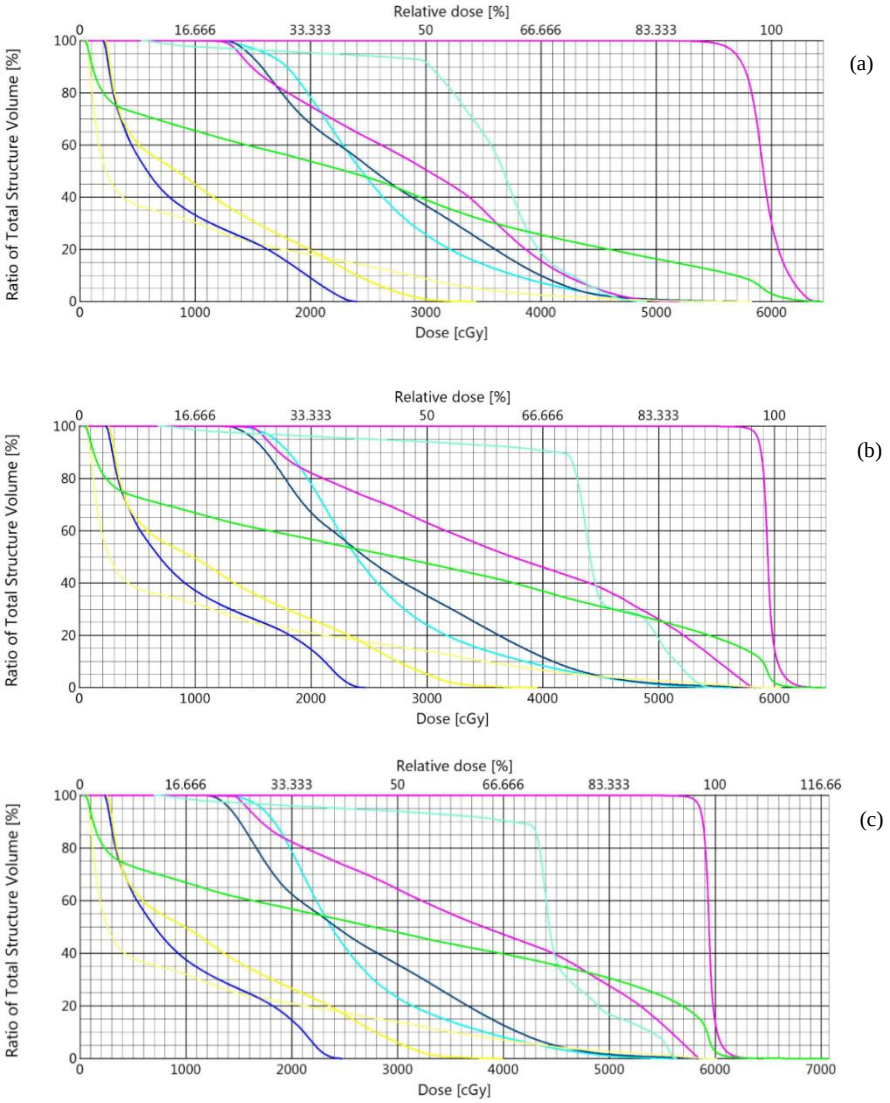


Figure 4. Dose Volume Histogram for every plan: (a) Automatic, (b) Manual, (c) Without NTO [Legends: = Eye_RT, = Eye_LT, = Brain, = Brainstem, = Spinal Cord, = Parotid_RT, = Parotid_LT, and = Whole body]

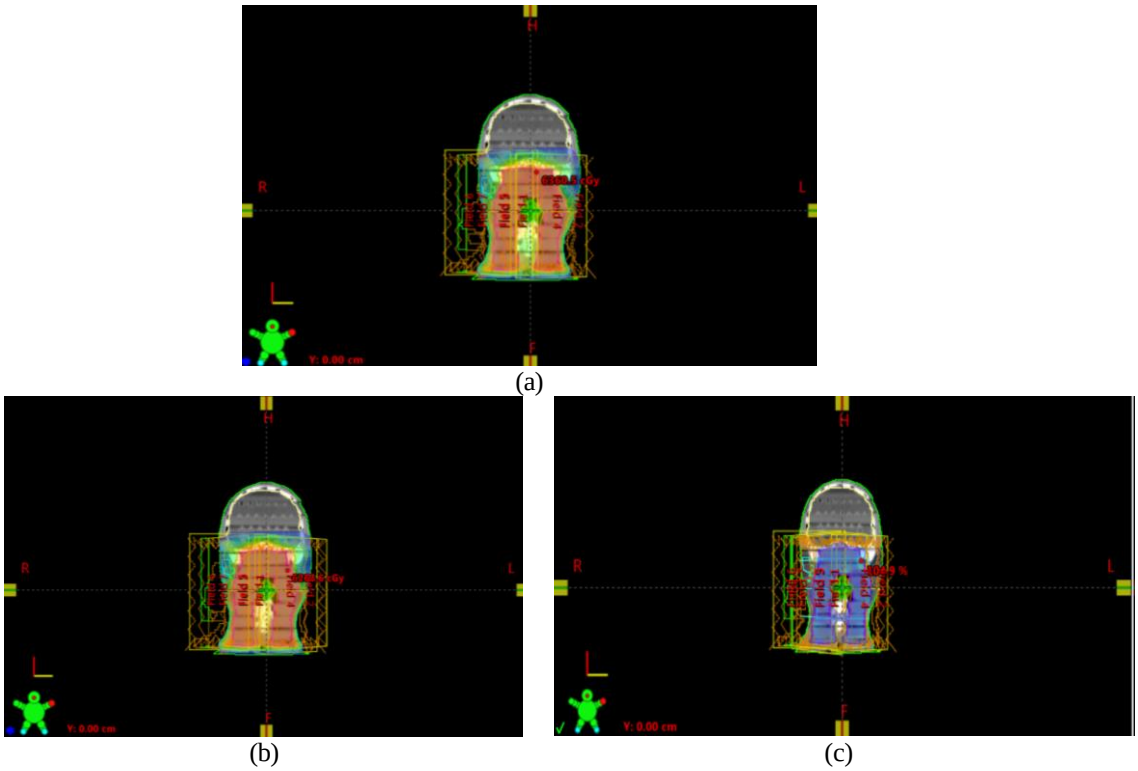
Table 4. Result of planning evaluation using quantification indices

	Automatic NTO	Manual NTO	Without NTO	Comprehensive Quality Index (Auto & Manual)
PTV				
HI	0.12	0.05	0.05	
CI	0.91	0.99	0.19	
GI	3.34	4.94	7.29	
Maximum Dose of OARs (cGy)				
Right Eye	2399.0	2373.0	2466.0	0.99
Left Eye	3440.4	3155.2	3995.0	0.92
Brain	5833.0	5961.3	6018.0	1.02
Brainstem	5199.9	5857.3	5838.0	1.13
Spinal Cord	4917.4	5064.0	5484.0	1.03
Right Parotid	5413.5	5633.4	5640.0	1.04
Left Parotid	5742.6	5894.4	5866.0	1.03

Table 5. Analysis of absorbed dose discrepancy between image analysis and Treatment Planning System (TPS)

Organs	Plans	Absorbed dose (cGy)		%ΔD	*P-value*
		Image Analysis	TPS		
PTV	Automatic NTO	202.14 ± 4.13	201.66 ± 4.23	0.23	0.02
	Manual NTO	200.60 ± 3.02	198.11 ± 1.62	1.26	0.00
	Without NTO	44.40 ± 0.59	197.59 ± 1.77	4.99	0.30
Right Eye	Automatic NTO	42.60 ± 0.85	41.68 ± 0.97	6.52	0.088
	Manual NTO	48.39 ± 0.61	44.91 ± 0.86	5.14	0.090
	Without NTO	41.82 ± 0.44	43.78 ± 0.71	9.53	0.090
Left Eye	Automatic NTO	32.96 ± 0.53	43.05 ± 0.78	2.88	0.089
	Manual NTO	35.58 ± 0.73	35.04 ± 0.81	5.96	0.091
	Without NTO	97.07 ± 1.78	35.88 ± 0.52	0.84	0.088
Brain	Automatic NTO	145.37 ± 1.02	102.92 ± 0.38	10.88	0.001
	Manual NTO	150.10 ± 3.47	143.84 ± 1.80	1.06	0.012
	Without NTO	155.09 ± 2.04	147.96 ± 1.70	7.20	0.028
Brainstem	Automatic NTO	203.41 ± 1.73	135.70 ± 8.03	14.29	0.089
	Manual NTO	195.94 ± 4.32	179.38 ± 1.45	13.40	0.090
	Without NTO	129.04 ± 4.40	165.78 ± 3.88	15.39	0.089
Spinal Cord	Automatic NTO	150.46 ± 3.26	127.58 ± 3.53	1.15	0.009
	Manual NTO	178.69 ± 1.79	153.59 ± 10.42	2.03	0.151
	Without NTO	105.03 ± 1.55	163.98 ± 13.00	8.16	0.043
Right Parotid	Automatic NTO	98.88 ± 3.33	107.30 ± 6.91	3.63	0.092
	Manual NTO	121.69 ± 4.24	100.06 ± 11.45	9.28	0.090
	Without NTO	70.34 ± 0.76	104.39 ± 13.22	14.22	0.088
Left Parotid	Automatic NTO	95.42 ± 1.45	77.36 ± 6.78	9.07	0.094
	Manual NTO	102.86 ± 2.04	96.10 ± 9.01	1.61	0.093
	Without NTO	102.86 ± 2.04	119.80 ± 20.03	16.47	0.090

Abbreviations: NTO, Normal Tissue Objective; PTV, Planning Target Volume.



(a) (b) (c)

Figure 5. Dose color-wash in planning using (a) Automatic NTO setting, (b) Manual NTO, (c) Without NTO planning. Areas with the highest dose (red) include nodal areas (cancer sites). Visual dose color-wash of each variation's axial, sagittal, and coronal sides shows areas covered by doses less than 107% (6420 cGy) of the prescribed dose (6000 cGy).

Based on Table 5, planning with Automatic NTO and Manual NTO shows a tolerable dose discrepancy with a discrepancy value of less than 5%, so planning is in accordance with the TRS 398 protocol on dose verification for PTV. The results of dose discrepancy calculations in the three plans showed that the absorbed doses of PTV and OAR were mostly overestimated, with the measured absorbed doses greater than the absorbed doses of TPS. A p-value of less than 0.05 indicates a statistical difference between the measured and TPS-absorbed doses.

Dose Colorwash Analysis

The dose colorwash analysis used in TPS evaluation considers the dose distribution visualized in the dose color-wash feature as shown in Figure 5. This feature displays the dose distribution in the target area and around the target by showing the under and over-dose marked by different colors. The colors show that the blue color is marked as under dosage (low dose) to overdosage (high dose), which is marked in red [21].

Discussion

The DVH analysis assesses organ-at-risk (OAR) restriction around the target volume, adhering to QUANTEC and CORSAIR guidelines for dose tolerance. Table 4 quantifies HI, CI, and GI indices, consistently showing good HI values. CI is notably lower without NTO, indicating poor conformity. Manual NTO demonstrates improved HI compared to Automatic NTO, suggesting a more homogeneous dose distribution. NTO settings notably enhance conformity between prescribed dose and PTV, essential for clinical safety. Automatic NTO is recommended for clinical planning, as it enhances treatment planning quality, as supported by Indrayani's study [10]. This emphasizes the necessity of NTO settings for optimal treatment planning, particularly to ensure adequate conformity and dose distribution within the prescribed parameters for clinical safety and efficacy.

In this study, there is a presumption about the factor that causes the uncertainty between the film analysis and the absorbed dose predicted by the TPS system to have a discrepancy of more than 10%. This conjecture lies, among others, in the spatial resolution of the film, which cannot read doses that are too low. This assumption is supported by the fact that the EBT3 film is optimal in reading films irradiated with a dose of at least 50 cGy [22]. The large air gap between each phantom iris also affects the penetration performance of the dose to be absorbed by the film, allowing the received film dose to be smaller or larger than the absorbed dose predicted by TPS [23]. Based on the mean pixel analysis, the EBT3 film used in this study is sensitive in acquiring 30 – 210 cGy doses.

The gradient index evaluates the dose fall-off outside the PTV based on 100% of the volume irradiated by the prescription dose. Based on Table 4, the lesser the gradient index, the fewer the possibilities of radiation toxicity in normal tissues. The gradient index indicates steepness outside the PTV, reducing the adverse effects on surrounding tissues. However, this study concluded that planning with Manual NTO could not perform better withstanding more absorbed doses at the OAR around the PTV because the gradient index value was lower than Automatic NTO. The Without NTO plan shows the highest gradient index, indicating that this planning is not significant in reducing the absorbed dose by the OAR. The findings of GI analysis diverge from the assertions made by Indrayani [10], who contended that the manual adjustment of non-texture objects (NTO) could enhance the GI value.

The CQI calculations in Table 4 show that Manual NTO planning performs better for the right and left eye organs. The CQI values for OARs other than the right eye and left eye show that planning with Manual NTO is no better than planning with Automatic NTO in protecting the desired organs at risk. However, without the NTO plan, the nodal site is covered in dark blue; it is thought only to receive a low dose of less than 1000 cGy. The OARs of the brain and brainstem show high doses, as indicated in red. The dose that the PTV should absorb is 5700 – 6420 cGy, and the absence of hotspots indicates that the prescription dose is not well distributed, as Montero stated that dose color wash could represent the accuracy of dose distribution [24].

The study's scope was constrained by employing a head-neck phantom and focusing on a single case of head-neck cancer (HNC). The limited number of test results underscores an insufficient basis for substantiating the study's outcomes. Future investigations are strongly advised to incorporate a broader range of cases to enhance the study's validity. There's also a possible improvement in the experiment by adding more phantoms used with a boarder and wider variety of materials.

Conclusion

The study demonstrated the impact of NTO tools on Nasopharyngeal carcinoma treatment planning. Manual and Without NTO settings didn't improve outcomes compared to Automatic NTO, which showed lower maximum absorbed doses in OARs. Manual NTO yielded better results in HI and CI parameters, while Automatic NTO had the best GI values. However, CQI favored Automatic NTO for lower maximal doses. Dose color wash analysis revealed Without NTO performed worst, leading to inappropriate dose distribution. Manual NTO reduced hotspots in PTV compared to Automatic NTO.

Acknowledgment

The authors thank the management of MRCCC Siloam Hospitals Semanggi, South Jakarta, Indonesia, who has allowed us to do this study in radiotherapy facilities. The authors gratefully acknowledge financial support from the Institut Teknologi Sepuluh Nopember for this work under the project scheme of the Publication Writing and IPR Incentive Program (PPHKI) 2024.

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