



Analysis of Radiation Dose Distribution in Nasopharyngeal and Organ Cancer Cases at Risk with Linear Accelerator Radiotherapy 6 MV Photon Energy Using the IMRT Technique at Prof. Hospital. Dr. I. G. N. G. Ngoerah

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study aims to determine the distribution of radiation doses on PTV and OAR radioteraphy planning in RSUP. Prof. Dr. I.G.N.G Ngoerah, Bali, Indonesia does no exceed a predetermined limit. The research metode used is the value of Homogeneity Index (H), Conformity Index (CI), and

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the maximum value of radiation dose to the Organ At Risk (OAR), namely the right eye lens, left eye lens, brainstem, optic chiasma, and spinal cord. These data are compared with the provisions of ICRU report 83 and the maximum dose reference value for OAR. Using data from 30 nasopharyngeal cancer patients with a total radiation dose of 7000 cGy. Obtained a value for HI of 0.1214 with a t-test result of $0.459 > 0.05$ which means it is not significant. While the value for CI is 0.9850 with nonparametric statistical test results of $0.285 > 0.05$ which means it is not significant. The maximum dose value for the right eye lens is 772.7 cGy with a t-test result of $0.779 > 0.05$ which means it is not significant. For the maximum value of the dose in the lens of the left eye of 771.0 cGy with a t test result of $0.791 > 0.05$ which means it is not significant. For the maximum value of the dose in the brain stem of 5178.1 cGy with nonparametric test results of $0.686 > 0.05$ which means not significant. The maximum dose value at the optic chiasma is 4,837.2 cGy with a nonparametric test result of $0.225 > 0.05$ which means it is not significant. For the maximum value of the dose in the spinal cord of 4,663.3 cGy with a t test result of $0.958 > 0.05$ which means it is not significant.

Keywords: Conformity index; homogeneity index; intensity modulated radiation therapy; nasopharyngeal carcinoma; organ at risk.

1. INTRODUCTION

The nasopharyngeal carcinoma (NPC) is a type of cancerous tumor that arises from the epithelial cells and occurs in the nasopharynx. It is a prevalent form of malignancy in the head and neck area [1]. NPC in Indonesia is one of the most frequently found malignancies, ranking fifth after breast cancer, cervical cancer, lung cancer, and liver cancer. According to GLOBOCAN 2020 data, there are 19,943 new cases per year in Indonesia. Additionally, NPC contributes to approximately 13,399 deaths per year [2]. The commonly used treatment methods for NPC are surgery, chemotherapy, and radiotherapy. Radiotherapy is often the preferred treatment, as a single treatment with curative intent for early-stage NPC with limited tumor size, while high-stage NPC requires a combination of chemotherapy [3]. One of the radiotherapy devices is the LINAC, which is designed to accelerate the movement of charged particles such as electrons linearly, thus producing photon and electron beams [4].

To minimize healthy tissue around the cancer being exposed to radiation, the Intensity Modulated Radiation Therapy (IMRT) technique has been developed. In cases of NPC, there are many OARs, and if OARs receive sufficiently high radiation, it can cause unwanted side effects. Each OAR has a different sensitivity level and dose distribution at each position [5]. The study conducted is an analysis of dose distribution using the IMRT technique in cases of NPC, based on the radiation dose received by the target volume and critical organs around it.

1.1 Nasopharyngeal Cancer

Nasopharyngeal cancer is a common malignancy that occurs in the head and neck area. The types of nasopharyngeal cancer are Keratinizing Squamous Cell Carcinoma, Nonkeratinizing Cell Carcinoma, and Basaloid Squamous Carcinoma. Nasopharyngeal cancer is frequently found in productive-aged men, with the majority of cases occurring in Southeast Asia. Factors that can cause someone to develop nasopharyngeal cancer include gender, age, ethnicity, consumption of preserved foods, Epstein-Barr virus, and genetic factors [6].

1.2 Radiation Technique

The Treatment Planning System has two radiation techniques for calculating multiple radiation fields that do not have uniform intensity. One of the techniques available in the TPS is IMRT (Intensity Modulated Radiation Therapy). IMRT is a modern technique in radiotherapy that uses multiple radiation fields in its radiation with non-uniform intensity in each direction of the radiation field to achieve optimum dose distribution. The changes in radiation intensity on the LINAC machine are modified by creating several segments on each radiation field formed by the MLC based on the shape of the tumor target and the dose constraints of the organs at risk around the tumor. In IMRT, the MLC plays a role in collimating and attenuating the radiation that comes out of the LINAC machine according to the expected dose distribution. Furthermore, for the needs of homogeneity of the resulting dose distribution, the addition of a wedge filter or

compensator is still necessary to attenuate radiation in the required area [7].

To implement the IMRT technique, a TPS computer is required that can perform calculations for multiple radiation fields with non-uniform intensity from each direction of radiation inversely and a radiation machine that can provide radiation with non-uniform intensity as planned by the TPS computer [7].

1.3 Organ at Risk (OAR)

Organ at risk (OAR) or normal tissue surrounding the cancer is an organ that has a high sensitivity to radiation and is easily damaged when exposed to radiation. Radiotherapy planning should always consider the normal tissue structures surrounding the cancer site. OAR is a consideration as an organ that cannot receive large amounts of radiation beyond the established limits, as damage to a small amount of normal tissue can cause severe clinical symptoms [8].

1.4 The Homogeneity Index (HI)

The Homogeneity Index (HI) is the ratio of the minimum dose volume to the maximum dose volume that has been determined. Dose homogeneity in the target volume is determined by the value of HI. In ICRU Report 83, HI is defined as the uniformity of dose distribution in the target volume. The ideal value for HI is 0, which means that the entire dose in the PTV is homogeneous. The acceptable range for HI according to ICRU criteria is 0-0.3. HI is influenced by the minimum dose, maximum dose, and mean dose in the target. In ICRU Report 83 on IMRT, the maximum dose is replaced by the dose at 2% of the target volume, the minimum dose is replaced by the dose at 98% of the target volume, and the mean dose is replaced by the dose at 50% of the target volume [9].

1.5 The Conformity Index (CI)

The Conformity Index (CI) is the ratio of the volume of PTV coverage to the total PTV volume. The conformity of the dose distribution with the tumor target is determined by the value of CI. In ICRU Report 83, CI is defined as the degree of conformity of the prescription dose to the target volume and is formulated as an ideal value of 1, which means that the isodose curve for the prescription dose precisely conforms to

the PTV. The Conformity Index is a value that describes the ratio of the 95% PTV volume receiving the prescription dose to the total PTV volume [9].

2. RESEARCH METHODS

This research was conducted on 30 nasopharyngeal cancer patients at the Radiotherapy Sub-Installation of RSUP Prof. Dr. I.G.N.G. Ngoerah. The research stages involve simulating the patient using a CT-Simulator. The resulting image of the cancer will be sent to the TPS for imaging by a radiation oncology specialist to determine the target volume and OAR. Then, calculations will be performed on the Monaco TPS by a medical physicist using the IMRT technique with the setting of several parameters, including adjusting the total dose to 7000 cGy with 33 fractions and using 7 beam angles. From these stages, values of VPTV, V95%, D2%, D50%, D95%, and the distribution of the received dose by Organ At Risk will be obtained. The obtained values will be calculated to find the HI and CI values using equations:

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}} \quad (1)$$

Where:

D2% = the dose that covers 2% of the PTV volume (cGy)

D98% = the dose that covers 98% of the PTV volume (cGy)

D50% = the dose that covers 50% of the PTV volume (cGy)

$$CI = \frac{V_{95\%}}{V_{PTV}} \quad (2)$$

Where:

V_{95%} = the total volume receiving 95% of the dose (cm³)

V_{PTV} = the volume of the planning target volume in radiation therapy (cm³)

The HI value is compared with the acceptable range according to ICRU report 83 which is 0-0.3. The CI value is compared with the value set by ICRU report 83 which is 1. The OAR used in the study are the right eye lens, left eye lens, and brainstem. The maximum value of OAR will be compared with the reference maximum value for the lens which is 1,000 cGy and for the brainstem which is 5,400 cGy.

3. RESULTS AND DISCUSSION

The results of this study were obtained by analyzing the TPS results such as DVH (Dose Volume Histogram) and isodose curve. DVH provides information on the dose values received by the target volume and Organ At Risk (OAR). Meanwhile, the isodose curve illustrates the dose distribution in the target volume and OAR at a certain depth. Here is an example of TPS results in the form of DVH and isodose curve graphs from one of the nasopharyngeal cancer patients using IMRT technique.

Based on the research results, data from DVH statistics were obtained, including the dose

distribution that covers 98% of the PTV volume (D98%), the dose that covers 50% of the PTV volume (D50%), the dose that covers 2% of the PTV volume (D2%), the volume of PTV in the radiation target (VPTV), the volume that receives 95% dose (V95%), and OAR (right eye lens, left eye lens, brainstem, optic chiasm, and spinal medulla). From this data, calculations will be performed to obtain the values of HI and CI to be compared with the values specified in ICRU report 83, while the maximum dose value for OAR will be compared with the reference maximum dose value for OAR according to the book Radiation Oncology A Question-Based Review 2nd Edition. The results of the calculation and comparison of HI, CI, and OAR can be illustrated in the graph.

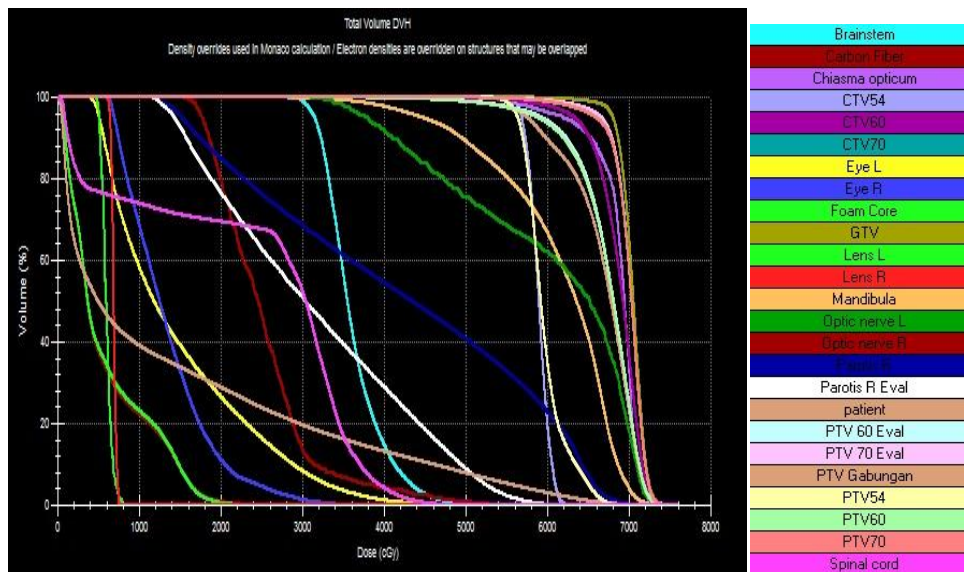


Fig. 1. DVH Curve of Nasopharyngeal Cancer Patient Using IMRT Technique

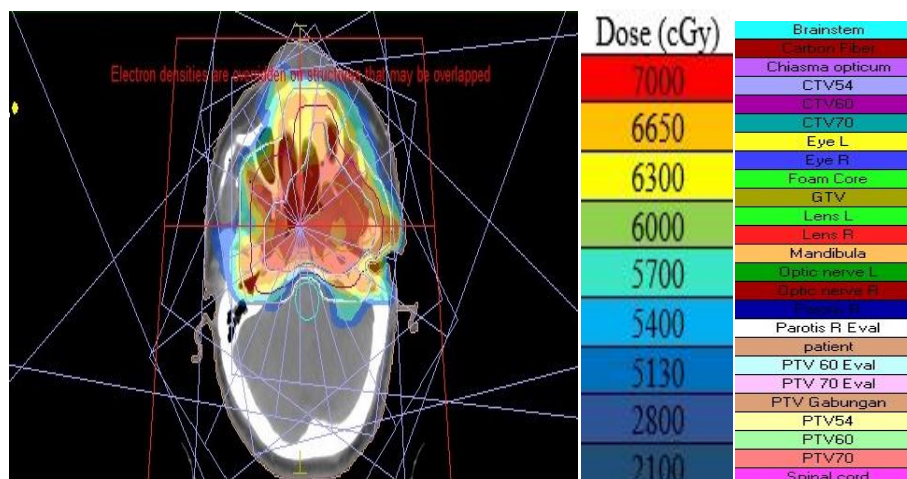


Fig. 2. Isodosis Curve Nasopharyngeal Cancer Patient Using IMRT Technique

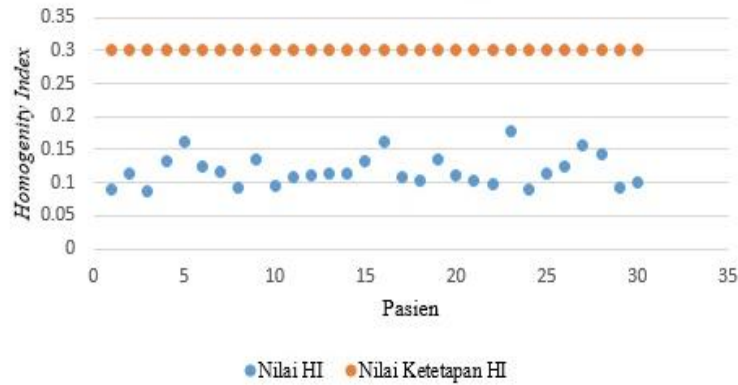


Fig. 3. Comparison graph of HI values with provisions for HI according to ICRU report 83

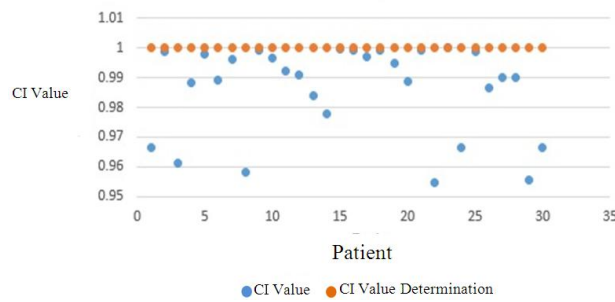


Fig. 4. Graph of comparison of CI values with provisions for CI according to ICRU report 83

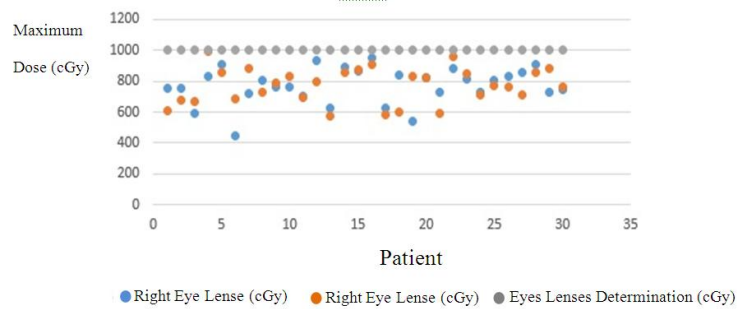


Fig. 5. Graph of comparison of the maximum value of the radiation dose for the right and left eye lenses refer to the maximum value of the radiation dose for the eye lens

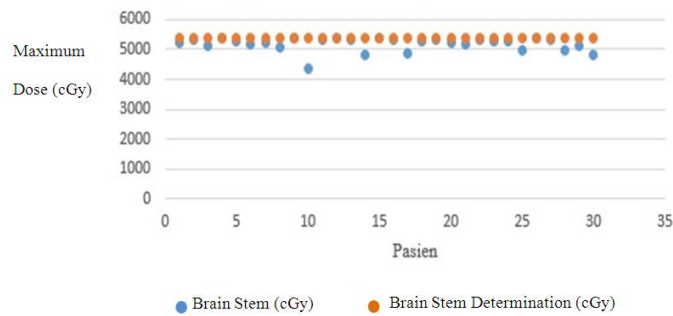


Fig. 6. Graph of comparison of the maximum value of the brainstem radiation dose with reference to the maximum value of the brainstem radiation dose

Table 1. Results of statistical test of dose distribution in nasopharyngeal cancer and OAR

	Average	Significance
<i>Homogeneity Index (HI)</i>	0,1214	0,459
<i>Conformity Index (CI)</i>	0,9850	0,285
Right Eye Lense	772,7	0,779
Left Eye Lense	771,0	0,791
Brainstem	5.178,1	0,686

Based on the calculations that have been performed on the HI, CI, and OAR values in nasopharyngeal cancer cases, statistical tests will be conducted on the results using SPSS software version 25 with a significance level of <0.05 to determine whether there is a significant difference between the calculated values and the predetermined values. The average values and the results of the statistical tests can be seen in the Table 1.

Based on Table 1, the significant difference between HI and CI values and the ICRU report 83 standards was tested using a one-tailed t-test with a significance level of <0.05. For HI value, the statistical test was conducted using a one-sample t-test with a significance value of 0.459 > 0.05, indicating that the null hypothesis is accepted or not significant. Meanwhile, for CI value, the statistical test was conducted using a Wilcoxon signed-rank test with a significance value of 0.285 > 0.05, indicating that the null hypothesis is accepted or not significant. From these results, it can be concluded that the HI and CI values are close to the ICRU report 83 standards, and the dose distribution obtained is homogeneous and suitable for the PTV.

The statistical analysis using t-test for the radiation dose distribution in the right and left eye lenses against the maximum reference dose for the respective lenses, yielded non-significant results with values of 0.779 and 0.791 respectively, both of which are greater than 0.05. Similarly, the Wilcoxon signed-rank test for the radiation dose distribution in the brainstem against the maximum reference dose for the same organ, resulted in a non-significant value of 0.686 which is greater than 0.05. These findings suggest that the radiation dose distribution in the Organs At Risk (OAR) did not surpass the maximum reference dose for the respective organs.

4. CONCLUSION

Based on the calculation results obtained from the radiation dose distribution values in

nasopharyngeal cancer cases and OAR, it can be concluded that the HI and CI calculation values do not exceed the limits according to ICRU report 83 in 2010 with non-significant statistical test results. Meanwhile, for the radiation dose distribution on OAR, specifically the right and left lenses of the eye and brainstem, the values do not exceed the maximum reference dose values for OAR with non-significant statistical test results. The radiotherapy planning carried out at RSUP Prof. Dr. I.G.N.G Ngoerah is in accordance with the applicable regulations, thus minimizing the potential side effects of radiotherapy.

CONSENT

As per international standard or university standard, patient(s) written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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