Original Research Article

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

ABSTRACT

Nasopharyngeal cancer (NPC) is a cancer that occurs in the nasopharynx which shows squamous cell changes. A technique utilized for treating cancer is through radiotherapy that employs X-rays which are accelerated and aimed with the aid of a LINAC apparatus. The assessment of the radiation dose dispersion was conducted by analyzing the Homogeneity Index (HI) and Conformity Index (CI) figures along with the highest radiation dose value that was absorbed by the Organs At Risk (OAR) which comprised the spinal cord, optic chiasma, brain stem, left and right eye lenses.The Treatment Planning System (TPS) contains a Dose Volume Histogram (DVH) curve, which was generated using data from 30 patients with nasopharyngeal cancer who received a total radiation dose of 7000 cGy. The resulting value for the Homogeneity Index (HI) was 0.1214, and the t-test result showed that it was not statistically significant at 0.459>0.05. Similarly, the value for the Conformity Index (CI) was 0.9850, and the nonparametric statistical test showed that it was also not statistically significant at 0.285>0.05. So that the HI and CI values of each patient are still within tolerance limits according to ICRU report 83 of 2010. 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.

Keywords: NPC, LINAC, OAR, HI, CI

1Introduction

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[2]. 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 [3]. 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 [4]. 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 [9].

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.

1.1Nasopharyngeal 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 [1].

1.2Radiotherapy

Radiation therapy or radiotherapy is a treatment for cancer using ionizing radiation. Non-ionizing radiation, in physics, refers to electromagnetic radiation with energies less than 10 eV [6]. Radiotherapy can be used as curative, palliative, or preventive therapy. Curative therapy is usually in the form of a single treatment for curing a cancer. Palliative therapy aims to improve the quality of life by eliminating cancer symptoms through the application of palliative radiation doses. Its application includes cases of brain and bone metastases as well as superior vena cava syndrome. Preventive therapy aims to prevent metastasis or recurrence by applying radiotherapy [7].

1.3Linear Accelerator (LINAC) Machine

The linear accelerator (LINAC) is a tool that employs high-frequency electromagnetic waves for propelling charged particles, including high-energy electrons, through a linear tube.The high-energy electron beam itself can be used to treat shallow tumors, or it can be modified by colliding with a target to produce X-rays that can be used to treat tumors deep within the body [8]. In LINAC, an accessory called the Multilief Collimator (MLC) is now equipped, which is a lead sheet that functions as a substitute for individual blocks to adjust the radiation intensity of the target [9]. The shape of the MLC is adjusted to the shape of the planned tumor/cancer in the Treatment Planning System (TPS), so that it can protect the Organ At Risk (OAR) [10].

1.4Treatment Planning System (TPS)

The Treatment Planning System (TPS) is a systematic process for developing a radiation therapy strategy. Planning involves a set of instructions for the radiation procedure and includes a physical description and dose distribution based on the available geometric/topographic information from imaging to ensure accurate radiation therapy. The goal of TPS is to adjust the dose to the target volume and reduce the dose to nearby organs at risk (OAR). This includes patient positioning, immobilization, gathering patient imaging data, deter\mining target and organ-at-risk volumes, obtaining target field shapes, dose distribution, and dose calculations [11]. In radiation therapy planning, one of the techniques used is IMRT. IMRT is a modern technique that uses multiple radiation fields with non-uniform intensity in each radiation field direction to achieve optimal dose distribution. Changes in radiation intensity on the LINAC machine are modified by creating multiple segments on each radiation field formed by MLC based on the shape of the target tumor and the dose constraints of the organs at risk surrounding the tumor. In the IMRT technique, MLC acts to collimate and attenuate radiation leaving the LINAC machine according to the expected dose distribution [12].

2 Research Method

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:

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

Keterangan :

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

Comment [SI1]: “Keterangan” should be in English

D98% = the dose that covers 98% of the PTV volume (cGy)
D50% = the dose that covers 50% of the PTV volume (cGy)

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

Keterangan :

Comment [SI2]: “Keterangan” should be in English

$V_{95\%}$ = the total volume receiving 95% of the dose (cm^3)
V_{PTV} = the volume of the planning target volume in radiation therapy (cm^3)

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 Result 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

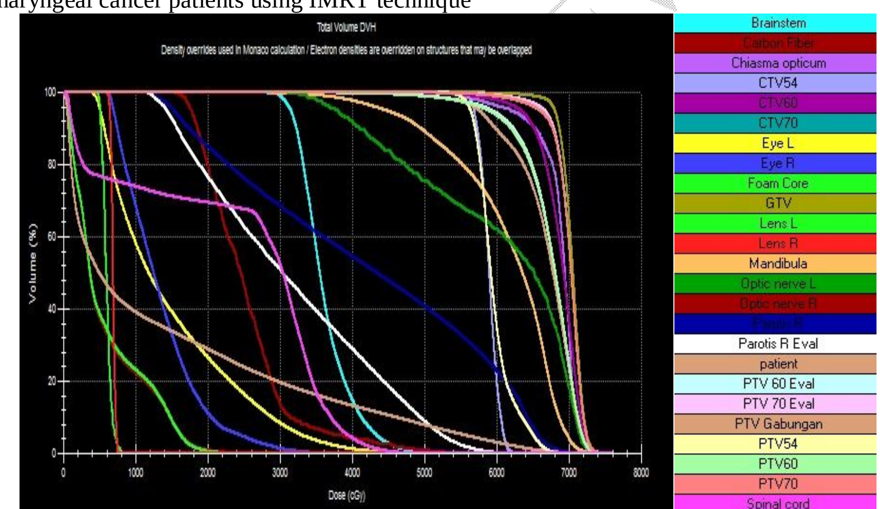

Figure 1 DVH Curve of NasopharyngealCancer Patient Using IMRT Technique.

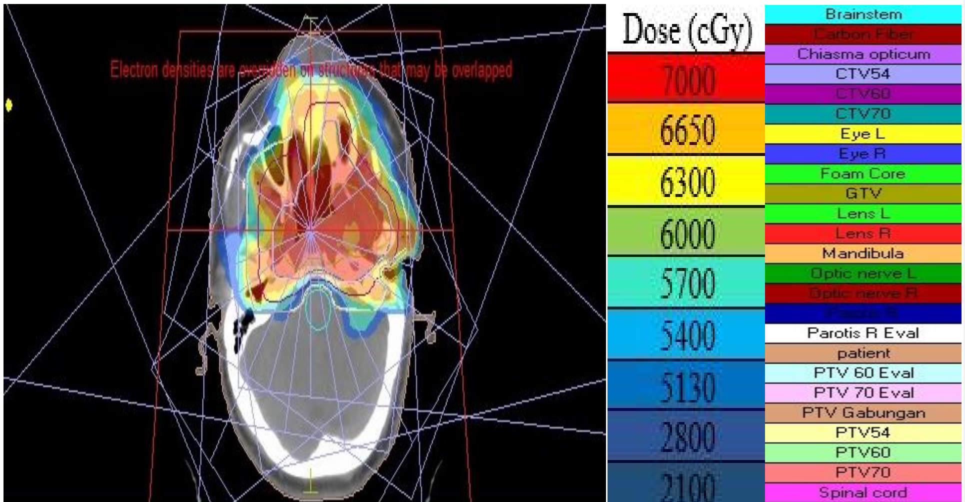

Figure 2 IsodosisCurve Nasopharyngeal Cancer Patient Using IMRT Technique.

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 below:

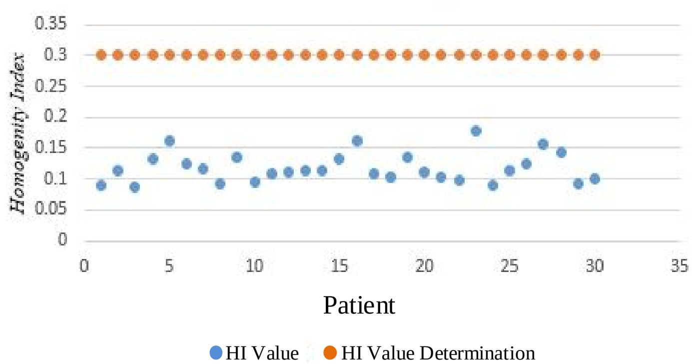

Figure 3 Comparison graph of HI values with provisions for HI according to ICRU report 83.

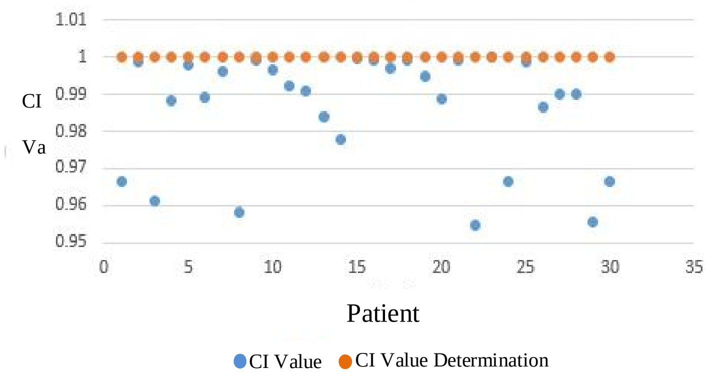

Figure 4 Graph of comparison of CI values with provisions for CI according to ICRU report 83.

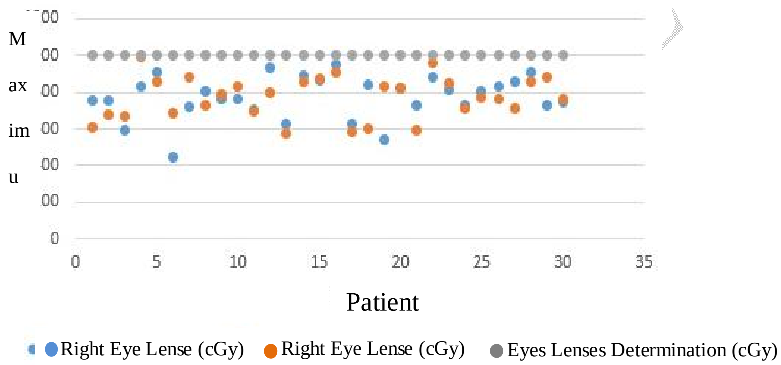

Figure 5 Graph of comparison of the maximum value of the radiation dose for the right and left eye lenses refer to the maximum value of the radiation dose forthe eye lens

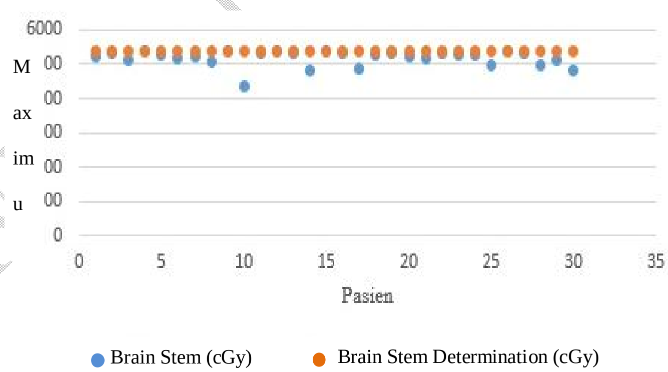

Figure 6 Graph of comparison of the maximum value of the brainstem radiation dose with reference to the maximum value of the brainstem radiation dose.

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 below:

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

	Average	Significance
Homogenity Index (HI)	0,1214	0,459
Conformity Index (CI)	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 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.

References

1 Chaeruddin, M. B. S., Hamsu K., Mochammad A. S., and Fathul D., 2017. Correlation Between Gender and Bcl-2 Expression in Nasopharyngeal Carcinoma Patients WHO III. Unram Medical Journal. Vol.6, No.3.

2 Nafisa, I. M., Mahendara S. U., Mas A. S., and Antony A. A., 2021. Profile of Nasopharyngeal Cancer Patients who Underwent Radiotherapy in Dr. Hasan Sadikin General Hospital Bandung. Indonesian Journal Of Cancer. Vol.16, No.02.

3 Milvita, D., Alimin M., and Mona V. 2018. Output Analysis of X-Ray Radiation Beams of LINAC Therapy Machines Based on TRS 398 IAEA on Fantom Ari at the Radiotherapy Installation of Andalas University Hospital. Journal of Physical Sciences. Vol.10, No.02.

4 Susworo, R., 2007. Fundamentals of Radiotherapy. Jakarta: UIPress.

5 Wibowo, A. S., Wiratno W., Bagus A., and Panji W. N., 2021. Neometry Verification of Nasopharyngeal Cancer WithEpid on the Linac Aircraft in the Radiotherapy Unit of the Radiology Installation of RSUP DR. Kariadi Semarang. Journal of Imaging Diagnostics

6 Podgorsak, E. B., 2003. Review of Radiation Oncology Physics : A Handbook For Teachers And Students, Vienna : IAEA.

7 Fitriyatuzzakiyyah, N., Rano K. S., Irma M. P., 2017 Cancer Therapy with Radiation: Basic Concepts of Radiotherapy and Its Development in Indonesia. Indonesian Journal of Clinical Pharmacy. Vol.6, No.4.

8 Khan F.M., 2018. The Physics of Radiation Therapy. New York: Wolters Kluwer.

9 Mahardika, M. A. J., Ratini, N. N., Sudarsana, I.W.B., and Mulyadi, F.M., 2022. Analysis of Electron Beam Output Constancy on the Elekta Precise Linear Accelerator (LINAC) Aircraft at the Radiotherapy Installation at Sanglah Hospital, Denpasar, Kappa Journal.Vol., No.2 .

10 Mayles, P., Nahum A., and Rosewald I.C., 2007. Handbook of Radiotherapy Physics Theory and Practice. London : Taylor & Francis.

11 Suhartono, B. H., Wahyu S. B., and Eko H., 2014. Photon Dose Distribution Using 3DCRT and IMRT Techniques in Whole Pelvic Radiation for Cervical Carcinoma. Periodic Journal of Physics. Vol.17, No.04.

12 Arianty, D., 2010. Optimizing the Number of Radiation Fields in IMRT Planning. Thesis, University of Indonesia, Jakarta