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Comparison of Dose Distribution to Target Volume and Organs at Risk using 3D CRT, IMRT, and VMAT Techniques in Glioblastoma Cases

Hamzah Fuadi[1], Heri Sutanto[1,*], Eko Hidayanto[1], Zaenal Arifin[1], Choirul Anam[1], Siti Fairus[2]
[1]Department of Physics, Faculty of Sciences and Mathematics, Diponegoro University, Semarang – Indonesia
[2]Department of Physics, University of Malaya, Kuala Lumpur – Malaysia
Corresponding author, E-mail: herisutanto@live.undip.ac.id

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ABSTRACT

The average lifetime risk of secondary cancer after irradiating glioblastoma radiation therapy to healthy organs shows that the *technique of volumetric modulated arc therapy* (VMAT) has a smaller risk of developing secondary cancer compared *to intensity modulated radiation therapy* (IMRT) and *three-dimensional radiation therapy* (3DCRT). Parameters of dose distribution, namely the target volume and dose received by the organs at risk (OAR), are used to compare these three techniques. The distribution of doses from TPS results in the form of DVH and isodose in the 3D CRT, IMRT, and VMAT techniques shows that the distribution of doses to healthy organs around the glioblastoma irradiation area is in the safe category and is still within tolerance limits. With VMAT, the PTV and CTV dose results were more optimal compared to the 3D CRT and IMRT techniques. 3D CRT showed a PTV dose value of 5551.8 cGy and a CTV of 5515.3 cGy. IMRT shows a PTV dose value of 6035.0 cGy and a CTV of 6018.8 cGy. VMAT shows PTV dose values of 6101.8 cGy and CTV of 6044.7 cGy. It can be seen that the distribution of doses to healthy organs in general in the VMAT technique is more optimal than the IMRT and 3D CRT techniques in protecting OAR.

Keywords : Radiotherapy, Three-Dimensional Radiation Therapy, PTV, CTV

I. INTRODUCTION

Primary brain tumors are a type of tumor that grows directly from tissue within the skull, including the brain itself, the central nervous system, and the membranes covering the brain [1]. The classification system used by the World Health Organization (WHO) classifies gliomas into four histological levels, which are defined based on the degree of cell similarity, malignancy, and an increasing degree of aggressiveness [2]. Glioblastoma generally appears at a median age of 64 years [3], but it can occur at any age, including childhood. Glioblastoma can be classified as primary or de novo, arising in the absence of a known

precursor, or secondary, in which a low-grade tumor transforms into a glioblastoma over time. Most glioblastomas are primary, and these patients tend to be older and have a poorer prognosis than patients with secondary glioblastomas [4].

Radiotherapy is a cancer treatment method that uses ionizing radiation, such as photons, electrons, protons, neutrons, and heavy ions, with the aim of destroying tumors or cancer cells [5]. In radiotherapy, high-energy radiation is used to destroy cancer cells, thereby preventing them from dividing and multiplying. In the case of medulloblastoma, radiation therapy is given as a curative therapy. Irradiation of the target tumor can be done through external beam radiation therapy and brachytherapy [6]. [7]. LINAC is a device that utilizes high-frequency electromagnetic waves to accelerate charged particles such as electrons, resulting in higher energy output through a linear tube. These high-energy electrons are employed in the treatment of superficial cancer layers. Alternatively, these electrons can be directed towards a target to generate photons used in treating cancer in deeper layers. [8]. The decision to choose radiotherapy as a treatment requires a good balance of judgment and clinical examination. In addition, the practice of radiotherapy requires not only excellent clinical skills but also appropriate technical expertise. [9]. Therefore, before carrying out the treatment, a step is required, namely treatment planning.

Treatment planning consists of a series of patient-related tasks that ultimately result in coordinated radiation and permit the prescription of radiation doses. System-treatment planning radiation (RTP) uses a mathematical model of the x-ray field to provide a 3D distribution of radiation doses placed around the body. Accurate dose calculation is very important in radiation treatment planning (RTP). Radiotherapy treatment uses the information provided by the treatment planning system (TPS), and clinical outcomes can be improved if the accuracy in dose calculation is further improved [10]. TPS (Treatment Planning System) is a radiotherapy planning system used to identify body contours, target areas, and organs at risk (OARs). It allows for the adjustment of beam input parameters, the distribution of radiation dosage, and the consideration of supporting equipment such as blocks, wedges, and others. Additionally, TPS generates isodose curves and other crucial information for radiotherapy planning. [11].

In recent years, radiotherapy irradiation techniques have been developed. This irradiation technique aims to reduce the radiation dose to organs at risk (OAR) while still providing optimal doses to target organs [12]. In this study, 3D CRT, IMRT, and VMAT were used as radiotherapy techniques, which were then analyzed for treatment planning. In the 3D CRT method, the main goal is to achieve an optimal dose in cancer tissue while minimizing radiation exposure in healthy tissue. In this technique, the radiation field is formed irregularly according to the shape of the tumor using the results of a CT scan in the Treatment Planning System (TPS). This allows three-dimensional determination of the shape of the tumor [13]. The IMRT technique is a more sophisticated conformal radiotherapy technique and is a development of the 3DCRT technique, where the radiation coverage is greater than 3DCRT [14]. VMAT is one of the irradiation techniques in radiotherapy where the gantry velocity, MLC, and dose rate continuously change over time. The gantry rotates around the patient. At the time of irradiation, the gantry generally rotates around the patient once or twice, but it can also be given additional rotation for more complicated cases [15]. However, the IMRT and VMAT techniques still have a weakness, namely the high cost of maintaining the equipment. Besides treatment planning, the dose distribution of this technique was also analyzed to determine the advantages of these three techniques. The treatment planning system (TPS) used in this research is TPS Eclipse.

In this study, the authors will compare the distribution of doses using the Dose Volume Histogram (DVH) on the Clinical Volume Target (CVT), Planning Volume Target (PTV), and Organ at Risk (OAR) for 3D CRT, IMRT, and V MAT techniques.

II. METHODS AND MATERIAL

2.1. Selection of Patient and Initial Imaging

This study utilized information from ten patients with brain cancer, specifically glioblastoma cases, who were treated with radiotherapy. Head images were scanned using a CT simulator with a slice thickness of 5 mm.

2.2. Target imaging and treatment planning

The photon energy used in the 3DCRT, IMRT, and VMAT techniques is 6 MV. The target volume and organs at risk (OAR) are delineated in the Eclipse treatment planning system (TPS). The clinical target volume (CTV) and planning target volume (PTV) are determined based on findings from physical examinations and CT scans. The CTV has a 0.5-cm margin around the PTV. The brainstem, eyes, and brachial plexus are defined as organs at risk. The total prescribed radiation dose is 59.4 Gy for the PTV volume, delivered in 33 fractions with a single treatment dose of 1.8 Gy.

2.3. Dose planning in the Eclipse treatment planning system (TPS)

The Eclipse TPS, developed by Varian Medical Systems, is a widely used software application in the field of radiation oncology. All patients undergo dose planning using the 3D CRT, IMRT, and VMAT techniques using the Eclipse TPS. The dose rate for 3D CRT ranges from 0 MU/minute to a maximum of 400 MU/minute, while for IMRT and VMAT, it ranges from 0 MU/minute to a maximum of 600 MU/minute. In the treatment planning process, information such as the DVH (dose-volume histogram) is obtained for the CTV, PTV, and OAR.

III. RESULTS AND DISCUSSION

Results

The research data that can be analyzed include the dose-volume histogram (DVH) and isodose results. DVH and isodose show the amount of dose received by the target volumes (PTV and CTV) as well as the OAR. Table 1 shows the patients who meet the study criteria in cases of glioblastoma.

Table 1. Average Dose Distribution Results

Volume Target	3D CRT (cGy)	IMRT (cGy)	VMAT (cGy)
PTV	5551.8	6035.0	6101.8
CTV	5515.3	6018.8	6044.7
Organ at Risk			
Brainstem	3865.1	4557.8	3451.0
Eye (R)	4711.3	4646.4	3546.9
Eye (L)	5039.4	3410.1	3607.3
Lens (R)	597.5	882.2	797.7
Lens (L)	955.3	1099.2	788.8
Optic Nerve (R)	4495.0	4599	3767.4
Optic Nerve (L)	4590.2	5019.4	4395.7

After determining the average dose received in the 3D CRT technique, the next step is to examine the dose distribution in OARs (organs at risk) using the 3D CRT technique in centiGray (cGy) units. The dose to the PTV is 5551.8 cGy, and the dose to the CTV is 5515.3 cGy, with the highest OAR dose recorded in the left eye at 5039.4 cGy and the lowest in the right lens at 597.5 cGy.

Moving on to the IMRT technique, the average dose received and the OAR dose distribution in the IMRT technique are examined in centigram (cGy) units. The dose to the PTV is 6035.0 cGy, and the dose to the CTV is 6018.8 cGy, with the highest OAR dose

recorded in the left optic nerve at 5019.4 cGy and the lowest in the right lens at 882.2 cGy.

Finally, the average dose received in the V MAT technique is examined, along with the dose distribution in OARs using the V MAT technique in centiGray (cGy) units. The dose to the PTV is 6101.8 cGy, and the dose to the CTV is 6044.7 cGy, with the highest OAR dose recorded in the left optic nerve at 4395.7 cGy and the lowest in the left lens at 788.8 cGy.

Then, a comparative evaluation of the dose distribution in the three techniques, 3D CRT, IMRT, and VMAT, was conducted in glioblastoma cases to determine the most optimal dose distribution in the target volumes PTV and CTV, as shown in Figure 1. From the results, it is observed that the dose distribution in PTV, CTV, and OAR in the VMAT technique is more optimal compared to the 3D CRT and IMRT techniques. The lowest OAR dose distribution is observed between the IMRT and VMAT techniques, as shown in Figure 1. These results indicate that the average dose distribution in the VMAT technique is lower compared to the 3D CRT and IMRT techniques.

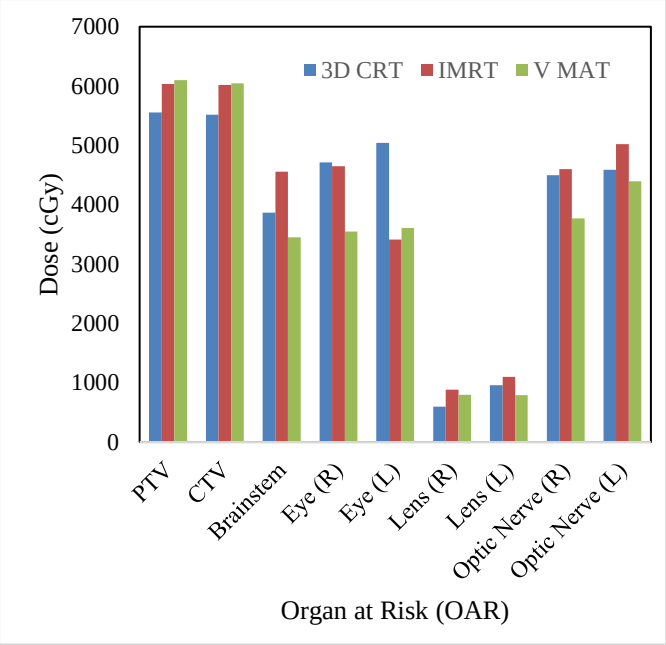

Figure 1. Comparison of Dose Distribution in 3D CRT, IMRT, and VMAT

Discussion

In this study, it is concluded that the radiation doses received by the organs at risk (OAR) with the 3D CRT, IMRT, and VMAT techniques are safe and play a crucial role in the quality of glioblastoma treatment with radiation. This is because the radiation doses to healthy organs do not exceed the established tolerance limits. Additionally, the radiation doses to the PTV are within the range of 95%–107% of the limits set by the International Commission on Radiation Units and Measurements (ICRU).

The results of this study also indicate that the radiation doses to the brainstem, eye, lens, and optic nerve in VMAT are more optimal compared to IMRT and 3DCRT. Additionally, the dose distribution in the average target volumes, PTV and CTV, is higher in VMAT compared to IMRT and 3DCRT.

Therefore, based on the analysis of this study, the VMAT technique has shown better capability in reducing the radiation dose received by organs at risk and minimizing the likelihood of secondary malignancies due to excessive radiation exposure to previously healthy organs in close proximity to the radiation area. This can serve as a guideline for the optimal use of radiation techniques based on the research findings.

Conclusion

The analysis of TPS results using DVH and isodose indicates that the dose distribution using the 3DCRT, IMRT, and VMAT techniques in the organs at risk surrounding the glioblastoma radiation area is safe and within the established tolerance limits. The dose distribution in the organs at risk for the VMAT technique is lower compared to IMRT, while the average dose to the target volumes for IMRT is slightly higher than VMAT. Based on the analysis of dose distribution in the target volumes PTV and CTV, it is evident that the dose distribution in the VMAT technique is more optimal compared to IMRT and 3DCRT. According to the findings of this study, the

VMAT technique should be considered for glioblastoma cases as it results in lower radiation exposure to healthy organs and OAR compared to IMRT and 3DCRT. Additionally, the treatment time is significantly shorter compared to other radiation techniques, including IMRT and 3DCRT. The shorter treatment time is another advantage of the VMAT technique.

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IV. REFERENCES

[1]. American Brain Tumor Association (ABTA). 2012. About Brain Tumors a. Primer for Patients and Caregivers. Chicago: ABTA. Pp. 76 – 78.

[2]. Louis, D.N., Ohgaki, H., Wiestler, O.D., & Cavenee, W.K. 2007. WHO Classification of Tumours of the Central Nervous System. 4th ed. Lyon, France: International Agency for Research on Cancer.

[3]. Thakkar, J.P., Dolecek, T.A., Horbinski, C., Ostrom, Q.T., Lightner, D.D., Barnholtz-Sloan, J.S., & Villano, J.L. 2014. Epidemiologic and molecular prognostic review of glioblastoma. Cancer Epidemiology, Biomarkers and Prevention.

[4]. Wilson, T.A., Karajannis, M.A., & Harter, D.H. 2014. Glioblastoma multiforme: State of the art and future therapeutics. Surgical Neurology International, 5, 64–62.

[5]. Podgorsak, E.B. Radiation Oncology Physics: A Handbook for Teachers and Students.

[6]. Garibaldi, C., Jereczek-Fossa B.A., Marvaso, G., et al. 2017. Recent advances in radiation oncology. Ecancermedicalscience.

[7]. Abdel-Wahab, M., Gondhowiardjo, S.S., Rosa, A.A., et al. 2021. Global Radiotherapy: Current Status and Future Directions—White Paper. JCO Glob Oncol;(7):827-842. doi:10.1200/go.21.00029

[8]. Khan, M.F. 2014. The Physics of Radiation Therapy, The 4th edition, Lippincott Wiliams and Wilkins, New York.

[9]. Barrett, A., Dobbs, J., Morris, S., & Roques, T. 2009. Practical Radiotherapy Planning. London.

[10]. Mohan, R. 1997. Proceedings of the XIIth International Conference on the Use of Computers in Radiation Therapy, Salt Lake City.

[11]. Kramme, R., & Hoffmann, K.F. 2011. RSP (Eds. Springer Handbook of Medical Technology.

[12]. Van der Veen J., Laenen A., & Nuyts, S. 2017. Modern radiotherapy techniques versus three-dimensional conformal radiotherapy for head and neck cancer. Cochrane Database of Systematic Reviews.

[13]. Brady, L.W., Heilmann, H., Molls, M., & Nieder, C. 2012. Technical Basic of Radiation Therapy. Berlin: Springer.

[14]. Allehyani, H.S. 2017. 3DCRT Versus RapidArc in Terms of Iso-Dose Distribution, Dose Volume Histogram (DVH) and Organs at Risk for Esophageal Cancer (EC) Dosimetric Study. American Journal of Clinical and Experimental Medicine;5(4):123.

[15]. Funderud, M, & Tømmerås, V.K. 2017. Evaluation of Robustness in Volumetric Modulated Arc Therapy (VMAT) plans for Head and Neck Cancer Patients.

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