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COMPARATIVE ANALYSIS OF INTENSITY MODULATED RADIATION THERAPY AND VOLUMETRIC MODULATED ARC THERAPY TECHNIQUES IN BRAIN TUMOR CASES TO MINIMIZE DOSAGE RADIATION TO ORGANS AT RISK

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Brain tumor, Radiotherapy, IMRT and VMAT

ABSTRACT
Radiotherapy technique is a systematic radiation planning method or procedure used for cancer treatment in the field of radiotherapy. Modern radiotherapy techniques allow the delivery of high doses at target volumes without dose escalation to at-risk organs, offering the possibility of better local control while maintaining a good quality of life. This study aims to analyze the difference in Treatment Planning System (TPS) results between Intensity Modulation Radiation Therapy (IMRT) and Volumetric Modulation Arc Therapy (VMAT) techniques in irradiation of brain tumors with Glioblastoma cases based on the dose received by the target volume and Organ at risk, as well as the results of the isodose curve. The research design used was Cross-Sectional and qualitative analysis. Data was obtained from simulation results in the Treatment Planning System (TPS) as a Dose Volume Histogram (DVH) by conducting Literature Studies, Observations, Documentation, and FGD Techniques. This research will be conducted in July 2023 at the Radiation Oncology Installation of Siloam MRCCC Hospital Semanggi. A study was conducted on 11 patients with brain tumors who received radiation therapy with IMRT or VMAT techniques. The results of this study showed no significant difference in dose received by the target volume and dose of Organ at risk in both techniques in statistical tests, but based on the average results descriptively showed that the VMAT technique was better than the IMRT technique. This is indicated by the dose received by the target volume according to the plan.

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INTRODUCTION

Cancer is the most important problem in the medical field and is one of the world's ten main causes of death. It is a malignant disease that can result in death in sufferers because cancer cells destroy other cells. Cancer is a form of malignant neoplasm (uncontrolled cell growth) that can spread to other body organs (Rizal Ryamizard1, CH Nawangsih P. 2, 2018) . Cancer is a medical condition in the form of the growth of abnormal and malignant cells in the body. The growth of cancer cells can occur in all parts of the body.

The brain is one of the most important parts of the human body, which regulates and coordinates the entire human body and thoughts. Brain function will be disrupted when the head is injured, especially if there is a tumor in the brain (Marita et al., 2014). So, the brain is one of the most complex organs in the human body. Brain tumor disease is the growth of abnormal brain cells in or around the brain unnaturally and uncontrollably. Brain tumors are divided into two, namely, primary and secondary brain tumors. (INDONESIA, 2020) . Brain tumors are the second cause of death in

cancer cases in children under 20. Brain tumors are also the second cause of death in all cancer cases in men aged 20-39. In addition, brain tumors are the fifth cause of death of all cancer patients in women aged 20-39 (Sari et al., 2014).

Glioblastoma multiforme (GBM) is a brain tumor with the highest rate reaching 38%. Meningioma and mesenchymal tumors account for 27%. The remainder consists of other primary brain tumors such as pituitary tumors, schwannoma, CNS lymphoma, oligodendroglioma, ependymoma, low-grade astrocytoma, and medulloblastoma (Sugiyanto & Bisri, 2019). Brain tumors have continued to increase in incidence over the last decade in several countries (INDONESIA, 2020). According to data from the International Agency for Research on Cancer, more than 126,000 people worldwide each year suffer from brain tumors. More than 97,000 people die 3, and according to reports from the Central Brain Tumor Registry of the United States 2018 (CBTRUS), brain tumors account for almost 2% of all cancers. The average annual incidence rate from 2007-2011 was 21.42% per 100,000 (Pertiwi et al., 2020). Brain tumor cases in the world are increasing every year. Every year in Indonesia, 300 patients are diagnosed with brain tumors. Not only adults, but brain tumors also attack relatively young children (Ramadhani et al., 2021). Based on data taken from medical records of Abdul Wahab Sjahranie Hospital in the Angsoka room connected from January 2015 to December 2015, the number of patients with Brain Tumor (Astrocytoma) as many as 54 patients were treated (Astuti, 2016). One hundred thirty-one cases of brain tumors at Haji Adam Malik Hospital in the period January 2018-December 2019, consisting of Meningioma 52 cases (40%), Glioma 34 cases (26%), 12 cases (9%) pituitary adenoma and 33 cases (25 %) brain metastases (Hutagalung & Dharmajaya, 2021). In the early stages, the tumor is difficult to detect because its boundaries are still unclear, the contrast is low, and sometimes it looks like normal tissue. Many people ignore the symptoms caused by brain tumors.

Symptoms that arise in patients with central nervous system tumors depend on the location and growth of the tumor. Patients with brain tumors may present with complaints due to increased intracranial pressure (headache, nausea, projectile vomiting), either due to mass effects or due to hydrocephalus, which in severe conditions can cause decreased consciousness (INDONESIA, 2020). Brain tumors are a disease that occurs due to the growth of abnormal tissue in the brain. Depending on the type, brain tumors can be benign or malignant. The anatomical health imaging approach is one way that can be used to determine the presence of tumors in the brain. For example, CT-Scan and Magnetic Resonance Imaging (MRI) (Ramadhani et al., 2021). Conventional treatment efforts for cancer usually include radiotherapy, surgery, and chemotherapy (Taufiqurrahman et al., 2020).

Radiotherapy is one of the main treatment options in cancer management, with approximately 50% to 60% of patients requiring radiation therapy at some stage. Radiotherapy is also an effective treatment for alleviating and controlling symptoms of locally advanced or recurrent cancer (Hiswara, 2017). The principle of radiotherapy is to kill as many cancer cells as possible with as little damage to normal organ cells at risk as possible (OAR). Radiotherapy can be used as curative and palliative therapy (Fitriatuzzakiyyah et al., 2017). So, radiotherapy is a cancer treatment procedure that is carried out using X-ray exposure. In short, the aim of radiotherapy is to kill and stop the spread of cancer cells and prevent the recurrence of cancer.

Modern radiotherapy techniques allow the delivery of high doses in target volumes without dose escalation to organs at risk, offering the possibility of better local control while maintaining a good quality of life. In its development, radiation techniques have been developed to minimize radiation affecting healthy cells. Several techniques currently used are 3D- Conformal Radiation therapy, Intensity Modulated Radiation Therapy, and Volumetric Modulated Arc Therapy (Taufiqurrahman et al., 2020). Radiotherapy techniques are systematic radiation planning methods or

procedures used for cancer treatment in the field of radiotherapy (Johnstone et al., 2018). Although there are still several advantages and disadvantages between the two techniques, both techniques are more accurate radiation planning methods with high precision, by the principles of radiotherapy where many organs are at risk around the brain, which will have fatal consequences if the dose is exceeded, such as damage or decline. Normal organ function if the dose value exceeds the existing tolerance limit value. Around the brain, there are also sensitive organs that need to be protected; the differences in treatment made me interested in analyzing and studying this research.

By comparing these techniques, it will be known which technique has the minimum radiation dose received by the organs at risk around the brain. Therefore, it is interesting to examine the comparative analysis of intensity modulation radiation therapy and volumetric modulation arc therapy techniques in brain tumor cases to minimize radiation doses to organs at risk. Apart from analyzing the dose to organs at risk, the output obtained from this research will be used as a policy brief in the form of a Draft SOP for radiotherapy radiation in brain tumor cases or hospital policy regarding brain tumor radiation cases.

This study aims to determine the comparative value of radiation doses affecting target organs and organs at risk using the radiotherapy techniques Intensity-Modulation Radiotherapy and Volumetric Modulation Arc Therapy with brain tumor cases and to create a Draft Standard Operational Procedure for irradiating brain tumor cases in radiotherapy installations.

The benefit of this research is to increase knowledge in radiotherapy regarding TPS results, which contain dose values and isodose curves, and develop knowledge about dosimetry of TPS results using IMRT and VMAT radiation techniques.

METHOD

The method used in this research is observation. Researchers made observations about irradiating brain tumors using IMRT and VMAT techniques at the Radiation Oncology Installation at Siloam Hospital MRCCC Semanggi. The population of this study is data from brain tumor patients who underwent radiation therapy at the Radiation Oncology Installation at Siloam Hospital MRCCC Semanggi. The number of patients with brain tumor irradiation with Glioblastoma cases used in this study was approximately 11 patients with 22 data. The sample for this research was taken from secondary data, which was the result of planning at the TPS at the Radiation Oncology Installation at Siloam Hospital MRCCC Semanggi. The Slovin formula is used to determine the research sample size with a level of significance that can be chosen because the population is less than 100 people, the total sample size is taken as a whole, but if the population is greater than 100 people, then 10-15% or 20-25 can be taken—% of the population. The research design used in this paper is cross-sectional and qualitative analysis. Data obtained from simulation results in the Treatment Planning System (TPS) in the form of a Dose Volume Histogram (DVH).

RESULTS AND DISCUSSION

Based on the output of research on 11 patients suffering from brain tumors for Glioblastoma cases using IMRT and VMAT radiotherapy techniques, the comparative value of the dose received by organs at risk was obtained, as well as the differences in the results of isodose curve images for IMRT and VMAT radiotherapy techniques.

1. Brain tumor cases using the IMRT technique or VMAT technique. All cancer patients have a target dose, and setting the target dose plays an important role in avoiding local and regional failure and, ultimately, metastasis. Clinical Target Volume (CTV) and Planned Target Volume (PTV) are descriptions of target volumes by the International Commission on Radiation Units

(ICRU) 50. CTV, a target volume that includes GTV and healthy tissue, has the potential for microscopic lymphogenic spread. PTV is a geometric concept used for therapy planning, dose specifications, size, and shape depending on the GTV and CTV and effects due to internal body movements and positions and therapeutic techniques used (PRATAMA, 2021).

Based on the average dose distribution value of 11 patients in brain tumor cases, the CTV value was 106.7 cGy with the IMRT technique and 101.4 cGy. The average dose distribution value of 11 patients in brain tumor cases was PTV 106.3 cGy with the IMRT technique and 100.9 cGy with the VMAT technique.

2. Brain tumor cases using the IMRT technique or VMAT technique. Organs at risk are organs or tissues that are particularly sensitive to radiation and can significantly impact the planned radiation dose planning process. Each critical Organ has a different level of sensitivity. Critical organs also have a threshold value for receiving radiation. It will harm normal tissue if it exceeds this threshold value (Lourrinx et al., 2023). Organs at risk of brain tumors are the brainstem and optic chiasm.

   Based on the results of the average dose received by 11 patients in brain tumor cases, the OAR Brainstem value was 62.2 cGy with the IMRT technique and 54.0 cGy with the VMAT technique for the average dose received by 11 patients in brain cases. The tumor obtained an OAR Optic Chiasm value of 81.1 cGy with the IMRT and 75.6 cGy with the VMAT technique.

3. Comparison of the dose received to the target volume
   a. CTV

      The research results found that the distribution value for the average dose received by CTV target organs in 11 brain tumor patients with the IMRT radiation technique was 106.7 cGy, and the VMAT radiation technique was 101.4 cGy. From the range of these two dose values, it can be concluded that the dose received by The CTV target organ in the IMRT radiotherapy technique is greater than in the VMAT radiotherapy technique (Niati et al., 2023).

      Statistical test results showed no significant difference in the dose received CTV between IMRT and VMAT techniques. Based on data from the 11 patients studied, the tumor location for glioblastoma cases can be determined close to the organs at risk (Brainstem and Optic Chiasm).

   b. PTV

      The research results found that the distribution value for the average dose received by PTV target organs in 11 brain tumor patients with the IMRT radiation technique was 106.3 cGy, and the VMAT radiation technique was 100.9 cGy. From the range of these two dose values, it can be concluded that the dose received by The PTV target organ in the IMRT radiotherapy technique is greater than in the VMAT radiotherapy technique (Indonesia et al., 2016).

      Based on statistical test results, there was no significant difference in the dose received CTV between the IMRT technique and VMAT techniques. Based on data from the 11 patients studied, the tumor location for glioblastoma cases can be determined close to the organs at risk (Brainstem and Optic Chiasm).

4. Comparison dose to Organ at risk
   a. Brainstem

      Based on the research results, distribution results were obtained for the average dose received by the brainstem organ in 11 brain tumor patients with the IMRT radiation

technique, which was 62.1 cGy, and the VMAT radiation technique, which was 54.0 cGy. From the range of these two dose values, it can be concluded that the dose received by the brainstem in the IMRT radiotherapy technique is greater than in the VMAT radiotherapy technique.

Based on the results of statistical tests, there was no significant difference in the dose received by the brainstem between IMRT and VMAT techniques. Based on data from the 11 patients studied, it was possible to determine the location of the brainstem organ at risk for glioblastoma cases close to the tumor organ.

b. Optic Chiasm

Based on the research, the distribution results for the average dose received by the optic chiasm organ in 11 brain tumor patients with the IMRT radiation technique were 81.1 cGy and the VMAT radiation technique 75.6 cGy. From the range of these two dose values, it can be concluded that the dose received by the optic chiasm in the IMRT radiotherapy technique is greater than in the VMAT radiotherapy technique.

Statistical test results showed no significant difference in the dose received optic chiasm between IMRT and VMAT techniques. Based on data from the 11 patients studied, it was possible to determine the location of the Optic Chiasm organ at risk for glioblastoma cases close to the tumor organ.

5. The most appropriate technique for radiotherapy for brain tumors in cases of Glioblastoma

Based on the analysis results in this study, it can be concluded that the IMRT and VMAT techniques for brain tumor radiotherapy radiation based on statistical tests do not show a significant difference in the dose received by target organs and organs at risk.

However, descriptively, the VMAT technique obtains a more minimal dose than the IMRT technique in terms of dose distribution to target organs and radiation dose to organs at risk, especially in the case of Glioblastoma in brain tumor irradiation.

From several other aspects, the advantage obtained from the VMAT technique is that the radiation time is shorter compared to the IMRT technique because, during the radiation process using the VMAT technique, the distribution of the dose given is more volumetric where the gantry also rotates clockwise or counterclockwise, the MLC shifts and follows from contour the tumor volume so that the radiation dose to the target organ can be minimized.

6. Draft Standard Operational Procedures for irradiation of brain tumor cases in radiotherapy installations

Stages such as comparative analysis, literature study, observation, and discussion have been carried out in this research and have also been made into a systematic arrangement in the form of a draft SOP for irradiation of brain tumor cases, which is included in the attachment. The purpose of preparing this draft SOP is as a reference for supporting parts of radiotherapy installations in determining the selection of radiotherapy techniques.

CONCLUSION

Based on the results and discussion above, it can be concluded that the average value of the Clinical Target Volume dose distribution in brain tumor cases using the IMRT technique is 106.7 cGy, the VMAT technique is 101.4 cG y, and the average value of the Planning Target dose distribution The volume in brain tumor cases using the IMRT technique was 106.3 cGy and the VMAT technique was 100.9 cGy. The average value of the dose received by the OAR Brainstem in brain tumor cases using the IMRT technique is 62.2 cGy. The VMAT technique is 54.0 cGy, and the average value of the dose received by the OAR Optic Chiasm in brain tumor cases using the IMRT

technique is 81.1 cGy, and the VMAT technique is 75.6 cGy. The results of the comparison range show that the target volume that received a higher dose was when using the IMRT radiotherapy technique compared to the VMAT radiotherapy technique, but this was not very significant from the statistical test results. The results of the comparison range show that organs at risk receive a lower dose with the VMAT radiation technique compared to the IMRT radiation technique, but this is not very significant from the statistical test results. From the analysis of calculations and comparisons above, it can be concluded that the IMRT and the VMAT techniques for brain tumor radiotherapy do not show a significant difference in the dose received by the target organ and the Organ at risk. The descriptive research results found that the IMRT technique's average value was higher than the VMAT technique, both in the distribution of target organs and the dose to organs at risk.

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