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Comparison of Automatic Beam Angle Optimization and Manual using Intensity Modulated Radiation Therapy Planning in Brain Tumors

Baiq Septika Rufaida[1], Rinarto Subroto[2], Heri Sutanto[1], Wahyu Setia Budi[1].

[1]Departement of Physics, Faculty of Science and Mathematics, Diponegoro University Semarang, Indonesia.

[2]Regional General Hospital of NTB Province, 84371, Mataram, West Nusa Tenggara, Indonesia.

Abstract – This study aims to determine and analyze the results of planning intensity modulated radiation therapy (IMRT) in cases of brain tumors using conformity index (CI) and homogeneity index (HI) calculations between automatic beam angle optimization (BAO) and manual on IMRT delivery techniques sliding window (SW). The values obtained will then be used to determine the most optimal beam angle in IMRT radiotherapy planning, especially for cases of brain tumors. Nine brain tumor patients underwent IMRT radiotherapy planning using an experimental approach. Brain tumor images are sent to the treatment planning system (TPS) to determine the isocenter, determine energy, determine the number and direction of gantry angles, then IMRT planning is conducted by giving dose volume and priority to organs at risk (OAR) according to QUANTEC used in radiotherapy planning the brain manually, while the automatic technique uses the BAO application. Then the IMRT optimization was conducted with the delivery technique, namely the SW. The results of this study, the CI value of the automatic of (0.970±0.021) is better than the manual technique of (0.941±0.021) with a difference in the percentage value of (p=0.021) is significant, due to the automatic technique of PTV volume ratio which received 98% of the prescription dose is relatively large and the monitor unit (MU) obtained is less than manual technique, but the manual technique is better at protecting OAR. The value of HI using the manual technique of SW method (1.070±0.035) is better than the automatic technique of the SW method of (1.119±0.057) with a difference in the percentage value of (p=0.038) which is significant, due to the range of homogeneity in the manual technique for relatively small volumes than the automatic technique of the maximum dose using PTV parameters and the number of fields used is 5 fields

Keywords – conformity index; homogeneity index; beam angle optimization; intensity modulated radiation therapy; sliding window.

I. INTRODUCTION

National Program for Cancer Registries (NPCR) provides data from 2006 to 2010 0f all ages for about 313.780 cases of primary brain and central nervous system (CNS) tumors, of which 42% occurred in men and 58% in women. The overall average rate per year is 21.03/100.000 population, for children aged 0-19 years as much as 5.26/100.000 population and 27.38/100.000 population for adults [1] and from 2011 to 2015 the average level of the annual incidence of children aged 0-14 years is 4.99/100.000 population and aged 15-39 years is 11.20/100.000 population [2].

Brain tumors are divided into primary and secondary brain tumors. Primary brain tumors are tumors that start in brain cells that can spread to other parts of the brain and even the spine, while secondary brain tumors are the initial position of the spread of malignant tumors are the initial position of the spread of malignant tumors or metastases to other parts of the body. In Indonesia, information about the epidemiology of primary and secondary brain tumors is still lacking due to the fact that data collection on brain tumor cases is still not mandatory and the recording of brain tumor cases is only conducted on malignant brain tumors, so that benign brain tumors are often ignored. Tumors that cannot be completely removed by surgery, such as abnormal tumors and malignant tumors, require radiotherapy treatment methods [3].

Radiotherapy is an important modality in the treatment, especially in cases of brain and CNS tumors. Theoretically, brain and CNS tumors have two problems, namely 1) some critical and sensitive organs are located near the CNS and 2) most CNS tumors can recur locally so that radiotherapy treatment planning is needed that can help provide accurate treatment such as intensity modulated radiation therapy (IMRT) [4].

IMRT planning is done by inverse planning, starting with determining the dose distribution on the target and organs at risk (OAR) to get the optimal dose distribution by modulating the intensity of each field using dose optimization [5]. The working principle of inverse planning is to include the desired structure and objectives, so the computer will calculate and determine the number and direction of the beam, the shape of the field, and the intensity of the beam until the dose distribution is optimal. To get the optimal distribution of beam angles, it is done manually, namely selecting the beam angle repeatedly with trial and error on the dose volume and priority using OAR in accordance with quantitative analysis of normal tissue effects in the clinic (QUANTEC) based on the clinical experience of the planner using energy curves on area. The field is called the treatment planning system (TPS), but this manual approach takes a long time because it requires automatic optimization, namely beam angle optimization (BAO) [6], [7]. BAO is an IMRT radiotherapy planning system using a special optimization algorithm automatically to speed up selecting and determine the optimal number and direction of beam angle based on volume dose [8], [9]. Several previous studies on automatic BAO and manual [10]-[13] according to Srivastava et all, [11] Litoborska and Piotrowski [12] that both techniques have almost the same dose volume histogram (DVH) results on planning target volume (PTV) and OAR on BAO, monitor unit (MU) and segment values are better than manual.

TPS is part of the radiotherapy process which is conducted before the therapy process by making an isodose curve using a computer and used as an analysis before therapy is conducted which includes data collection for the reconstruction process, dose-matrix formation, dose-matrix geometry transformation, and isodose program [14]. DVH is a summary of the radiation dose distribution in the form of a graph of the radiotherapy plan conducted. To get the optimal dose distribution value on DVH, using optimization with conformity index (CI) calculations, namely the dose distribution between the specified dose area and homogeneity index (HI) calculations, namely the target volume dose inside the target and outside the target [15], [16] with IMRT delivery technique using conventional multi-leaf collimator (MLC), namely sliding window (SW). SW is also called dynamic, namely the continuous MLC leaf movement will maintain the spatial resolution, and the intensity remains in accordance with the optimal fluence using the inverse planning algorithm calculation [17].

Several previous studies on SW according to Kinhikar et all, [18] the SW method in image-guided radiotherapy is able to control tumors and protect OAR. Breast cancer cases using the SW method resulted in better dose homogeneity and lower doses received by the lung and heart [19]. Cornacchia et all, [20] SW IMRT methods in Hodgkin's Lymphoma (HL) cases is able to provide low doses to the lungs, heart, and breasts and is able to provide better results for CI values [21].

To find out how optimal the radiotherapy plan is using manual techniques by choosing the angle of the beam in the IMRT radiotherapy planning in brain tumor cases, and to prove the calculations in these cases using CI and HI with IMRT delivery techniques, namely the SW and SS methods.

The results obtained are expected to be used as a reference for medical physicists in planning for brain tumor IMRT radiotherapy.

II. Materials And Methods

This study used nine patients with brain tumor cases at the Radiotherapy Installation of the NTB Provincial General Hospital with Eclipse TPS version 13.7 (Varian Medical System). The steps of this research are planning for brain IMRT radiotherapy, patients who have been scanned using a CT simulator are then sent in the form of DICOM images using software to TPS, the CT images by Radiation Oncology Specialists are delineated cancer targets and OAR.

The steps of the research conducted can be seen in Figure 1, namely determining the isocenter, determining energy, determining the number and direction of the gantry angle, then optimizing IMRT planning by giving dose volume and priority repeatedly to OAR according to QUANTEC in planning brain radiotherapy manually or automatically until obtaining the distribution of the desired dose is shown in Table 1. The automatic technique in IMRT planning is equipped with a BAO menu so that it can determine the number and direction of gantry angles from a PTV, the data collection technique is almost the same as the manual technique, which differs when optimization is conducted, namely the automatic technique using the BAO application shown in Figure 2 and Figure 3, after that the IMRT delivery technique using the SW methods and dose calculation using the Anisotropic Analytical Algorithm (AAA).

Table 1. Limitation of the value of healthy tissue on OAR used in the brain based on QUANTEC [22], [23]

Organs at risk	Dose/Volume
Brain	Dmax <60
Brainstem	Dmax <60
Optic nerve/chiasm	Dmax <55
Spinal cord	Dmax =50
Lens	Dmax =10
Eye	Dmax <45

Data analysis was conducted quantitatively, namely the dose distribution was evaluated with reference to the ideal values of CI and HI. The CI is the ratio between the volume ratio of the PTV receiving 98% of the prescription dose to the total volume of PTV. While the HI is a value that describes the uniform distribution of the absorbed dose in the target organ [24]. With the maximum dose D_{max} and the prescription dose D_p.

$$CI = \frac{V_{98\%}}{V_{PTV}} \quad (1)$$

$$HI = \frac{D_{max}}{D_p} \quad (2)$$

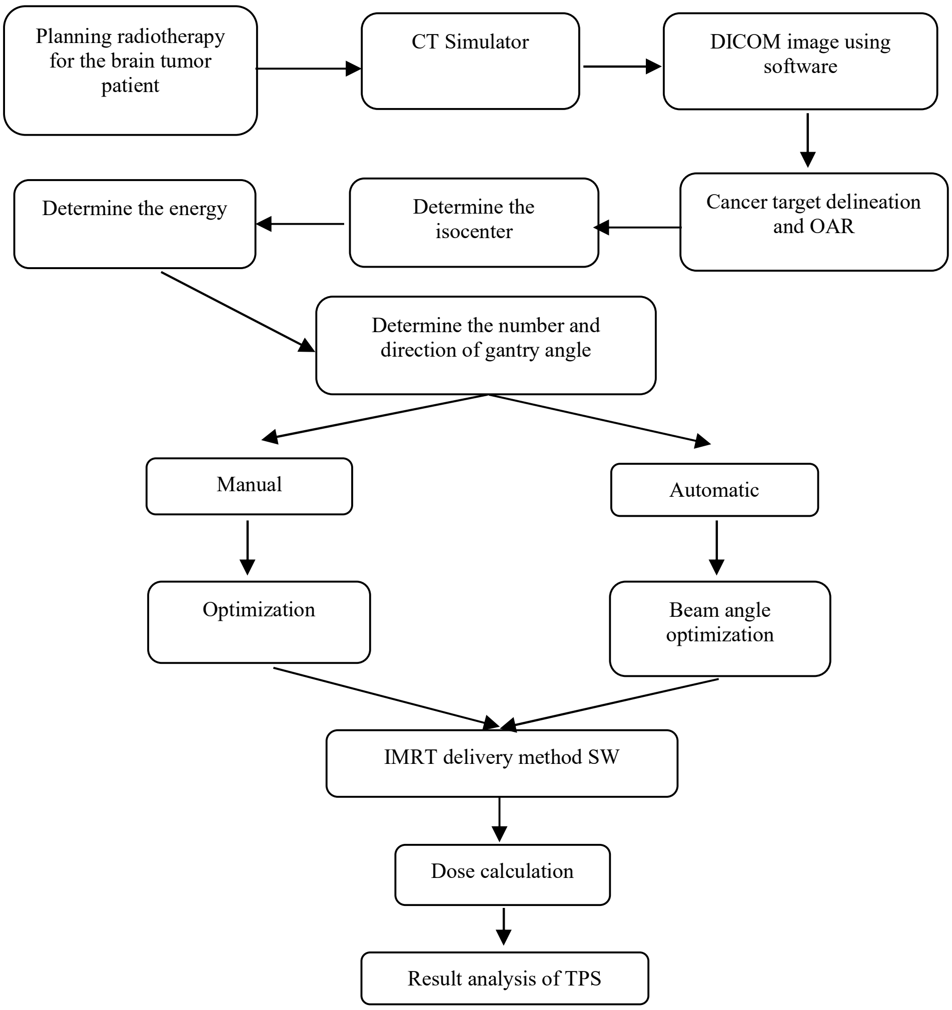

Figure 1. Steps of the research

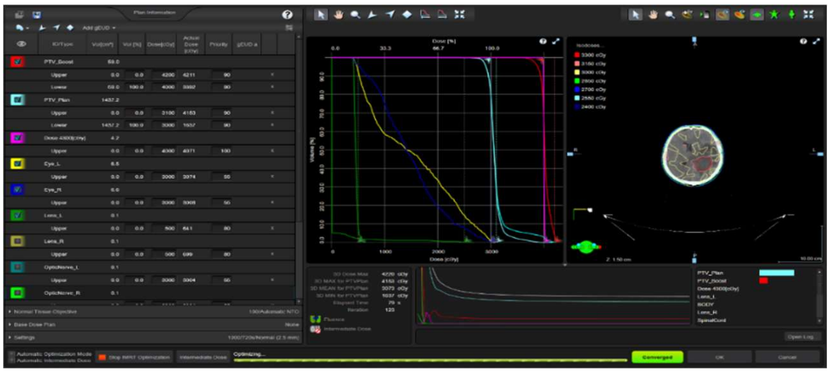

Figure 2. optimization manual

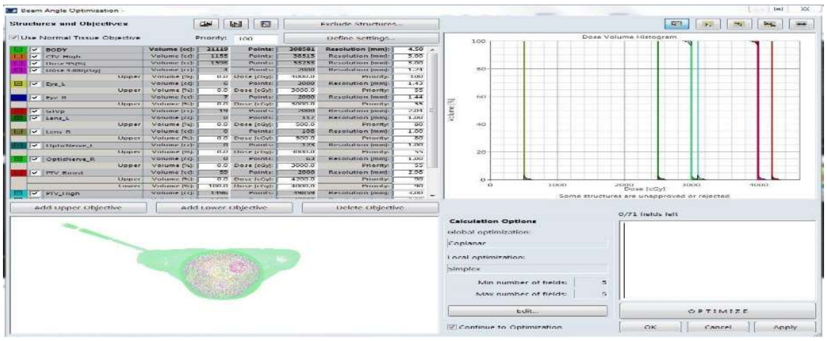

Figure 3. Automatic optimization using BAO application

III. RESULT AND DISCUSSION

Radiotherapy planning is something that must be done to find out that the radiotherapy plan has met treatment standards. Radiotherapy treatment aims to optimize the radiation dose delivered to the tumor by saving healthy tissue.

The direction of gantry angle used in the SW method of IMRT delivery is shown in Table 2.

Table 2. Direction on gantry angles

Patient	Direction of Gantry Angles	
	Manual	Automatic
1	0^0; 72^0; 144^0; 216^0; 288^0	0^0; 71^0; 181^0; 259^0; 304^0
2	0^0; 72^0; 144^0; 216^0; 288^0	59^0; 122^0; 172^0; 264^0; 338^0
3	0^0; 72^0; 144^0; 216^0; 288^0	5^0; 36^0; 76^0; 287^0; 314^0
4	0^0; 72^0; 144^0; 216^0; 288^0	5^0; 76^0; 125^0; 208^0; 269^0
5	0^0; 72^0; 144^0; 216^0; 288^0	61^0; 88^0; 162^0; 284^0; 335^0
6	0^0; 72^0; 144^0; 216^0; 288^0	71^0; 170^0; 223^0; 274^0; 330^0
7	0^0; 72^0; 144^0; 216^0; 288^0	17^0; 71^0; 167^0; 233^0; 284^0
8	0^0; 72^0; 144^0; 216^0; 288^0	56^0; 134^0; 172^0; 249^0; 350^0
9	0^0; 72^0; 144^0; 216^0; 288^0	41^0; 140^0; 218^0; 284^0; 335^0

Table 2 shown the direction of gantry angles in the manual technique commonly used in cases of the brain, while the automatic technique uses the BAO application, and the number of fields used is 5 fields.

Evaluation in radiotherapy planning to obtain optimal dose distribution in DVH using CI and HI in manual and automatic techniques.

Table 3. Conformity index

Patient	**Conformity Index Value**	
	Manual	**Automatic**
1	0.954	0.966
2	0.937	0.953
3	0.909	0.944
4	0.946	0.969
5	0.943	0.950
6	0.936	0.999
7	0.978	0.964
8	0.954	0.993
9	0.913	0.996
Average	0.941	0.970
Standard Deviation	0.021	0.021

Table 3 shows the CI value in the manual technique with an average value of 0.941 and the automatic technique with an average value of 0.970. The HI value is shown in Table 4, namely the manual technique obtained an average value of 1.070 and the automatic technique obtained an average value of 1.119.

Table 4. Homogeneity index

Patient	**Homogeneity Index Value**	
	Manual	**Automatic**
1	1.066	1.080
2	1.061	1.066
3	0.997	1.071
4	1.068	1.076
5	1.134	1.113
6	1.073	1.181
7	1.072	1.087
8	1.075	1.196
9	1.088	1.203
Average	1.070	1.119
Standard Deviation	0.035	0.057

The manual technique will be compared to the automatic technique, so that the statical significance between manual and automatic was evaluated using Wilcoxon signed-rank test (provided that the significance was $p<0.05$). The results obtained are shown in Table 5.

Table 5. The results of the percentage values of the conformity index and homogeneity index in manual and automatic techniques.

	Manual		Automatic		P-value
	Average	Standard Deviation	Average	Standard Deviation	
CI	0.941	0.021	0.970	0.021	0.021
HI	1.070	0.035	1.119	0.057	0.038

Table 5 shown the percentage values obtained the calculation of CI and HI using manual and automatic techniques, namely the comparison between manual and automatic obtained CI of (0.941 ± 0.021) and (0.970 ± 0.021) with a value of ($p=0.021$), HI of (1.070 ± 0.035) and (1.119 ± 0.057) with value of ($p=0.038$).

The ideal value of CI and HI is 1, so that if CI and HI are greater than 1, it indicates that the volume receiving the prescription dose exceeds the target volume and partially covers healthy tissue and if the CI and HI are less than 1, it indicates that the target volume is partially radiated. According to RTOG, if the ideal values of CI and HI are difficult to obtain, then CI and HI values between 1 and 2 are considered as planned, CI and HI values between 2-2.5 and 0.9-1 are considered small deviations, CI and HI values >2.5 and CI and HI<0.9 are large deviations [25], [26], [27]. The analysis of nine patients who underwent brain radiotherapy closest to 1 using IMRT delivery technique SW method in Table 3, namely the CI value shows that the automatic technique is more conformity than the manual technique, due to the PTV volume ratio automatic technique received 98% of the prescription dose is relatively large and the MU obtained is less than manual technique. Where, the amount of MU is related to the radiation dose to the whole body so as to minimize radiation in reducing long-term complications [11]. However, the manual technique is better at protecting OAR because the manual technique gets a relatively low maximum dose than the automatic technique. The average value is manual technique (0.941 ± 0.021) and (0.970 ± 0.021) automatic technique, so there is better conformity using automatic technique than manual technique and statistically significant difference with the value of ($p=0.021$).

Table 4 shows that the HI value tends to be above 1, this is in accordance with the research of Cao et al, [16] the HI value with the calculation of the maximum dose of the prescription dose tends to be above 1 so that the HI value close to 1 is a better homogeneity value. The distribution of HI using IMRT delivery technique SW method of manual technique is more homogeneous with an average value of HI (1.070 ± 0.035) than the automatic technique with an average value of (1.119 ± 0.057) and a statistically significant difference with a value of ($p=0.038$). The HI value for the manual technique is better than the automatic technique, due to the homogeneity range in manual technique for relatively small volumes than the automatic technique of the maximum dose using PTV parameters and the number of fields used is 5 fields.

IV. Conclusion

The results of the study that the CI value of the automatic technique of (0.970 ± 0.021) is better than the manual technique of (0.941 ± 0.021) with a difference in the percentage value of ($p=0.021$) with is significant, due to the automatic technique of PTV volume ratio which received 98% of the prescription dose is relatively large and the MU obtained is less than manual technique, but the manual technique is better at protecting OAR. The value of HI using manual technique of (1.070 ± 0.035) is better than the automatic technique of (1.119 ± 0.057) with the difference in the percentage value ($p=0.038$) which is significant, due to the range of homogeneity in the manual technique for relatively small volumes than the automatic technique of the maximum dose using PTV parameters and the number of fields used is 5 fields.

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