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The Use of 3D-CRT Technique in dose Distribution Analysis for Cervical Cancer Treatment Planning

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ABSTRACT

Three-Dimensional Conformal Radiotherapy (3D-CRT) is a technique used in designing a cancer treatment (treatment planning system) using radiation emitted through a gantry with direction, angle, number of fields, and radiation energy according to needs. Determination of direction, angle, number of fields, and radiation energy precisely aims to provide effectiveness in cancer treatment. The purpose of this study was to determine the efficient use of multiple gantry angles in cervical cancer using a LINAC machine with 3D-CRT technique. Data processing in this study was carried out using quantitative analysis techniques, namely descriptive statistics. This analysis technique uses secondary data obtained from the results of the description that has been carried out by doctors at the Radiotherapy Installation. Data processing was carried out by carrying out a treatment planning system on 7 patients with each patient receiving planning using 4 gantry angles and 6 gantry angles. These results are visualized in the form of tables and graphs of absorbed doses received by patients. Based on this study, it can be concluded that using the 3D-CRT technique in cases of cervical cancer, using 4 gantry angles is more efficient than using 6 gantry angles.

I. Introduction

According to data from the Global Cancer Observatory (Globocan, 2020), as many as 36,633 (17,2%) recorded cancer cases were diagnosed in Indonesia and from data it was found that cervical cancer is in second place after cancer breast[1]. According to the Ministry of Health (Ministry of Health, 2018), cancer cases Cervical disease occurs in 23.4 per 100,000 population with an average death rate reached 13.9 per 100,000 population[2]. Cervical cancer is difficult to detect and can cause morbidity, infertility and death if not prevented. Cervical cancer treatment can be done through radiotherapy, such as the 3D-CRT technique[3],

Some studies show better results with the use of different radiotherapy techniques to treat cervical cancer. Therefore, research was conducted to analyze optimal radiotherapy techniques for the treatment of cervical cancer at Abdul Wahan Sjahranie Regional Hospital.

II. Method

This study was designed to analyze the comparison of dose distribution at 4 gantry angles and 6 gantry angles so that it is known the efficient use of gantry in cervical cancer using 3D-CRT technique with 2 categories, namely the use of 4 gantry angles (0°,90°,180°, and 270°) and using 6 gantry angles (0°,40°,150°,180°,220°,and 320°) with the equivalent dose used for cervical cancer treatment of 5040 cGy and using a 6 MV photon radiation beam. For planning data, it is secondary data on cervical cancer patients taken in 2022 then the dose administered to patients is carried out directly by researchers, totaling 7 patients, each patients will receive 2 treatments, namely a 4 angle gantry and 6 angle gantry planning design using xio software. To carry out a treatment planning system on patients,

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where this research was carried out at the Abdul Wahab Sjahranie Hospital Radiotherapy Installation and the Basic Physics Laboratory of FMIPA Mulawarman University which was carried out from Januari 2023 to July 2023, and the analysis technique

III. Results and Discussion

1. In our study, we evaluated the effectiveness of radiation dose distribution by comparing the absorbed dose received by the target volume when using 4 gantry angles versus 6 gantry angles. This assessment involved analyzing data from 7 patients.

The comparison was based on two key metrics: the maximum dose delivered and the dose received by 95% of the Planning Target Volume (PTV). By examining these values, we aimed to determine the impact of gantry angle variations on dose distribution accuracy and potential implications for treatment efficacy

Table 1. Absorbed dose received by the target volume using 4 gantry angles and 6 gantries

Patients	*Max Dose* (5392,8 cGy)		PTV dose 95% (4788 cGy)	
	4 gantry corners	*6 gantry corners*	*4 gantry corners*	*6 gantry corners*
1	5373	5359	4870	4770
2	5317	5337	4800	4340
3	5350	5336	4860	4840
4	5380	5301	4800	4710
5	5292	5357	4860	4810
6	5359	5394	4840	4810
7	5392	5336	4860	4870

Max dose is the maximum dose that can be received by the cancer volume, where the value obtained in the planning results must not exceed 107% of the equivalent dose. In this case, the equivalent dose used is 5040 cGy, so the dose received in the cancer volume must not exceed 5392.8 cGy.

PTV dose 95% is the minimum dose of 95% that must be received by the cancer volume, where the value obtained in the planning results must not be below 95% of the equivalent dose used. In this case, the equivalent dose used is 5040 cGy, so the dose received in the cancer volume must not be less than 4788 cGy.

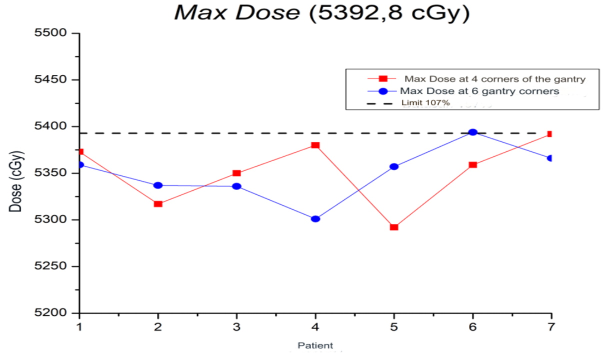

Fig 1. Comparison graph of the maximum dose obtained from seven patients using 4 gantry angles and 6 gantry angles.

In Figure 1, it can be seen that the results obtained from 7 patients using 4 gantry angles, all patients received a dose below the maximum dose compared to the use of 6 gantry angles where the 6th patient received a dose above the maximum dose. So it can be concluded that the use of 4 gantry angles is better than the use of 6 gantry angles when viewed from the max dose obtained after planning.

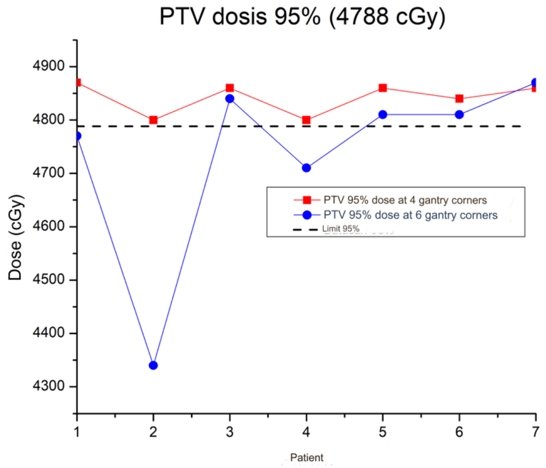

Fig 2. Comparison graph of 95% dose FTV obtained from seven patients using 4 gantry angles and 6 gantry angles.

In Figure 2, it can be seen that the planning results for the use of 4 gantry angles from the 7 patients obtained values that were above the minimum dose required, while for the use of 6 gantry angles in patients 1, 2, and 4 obtained doses that were below the minimum dose required. When the PTV dose value of 95% is below the dose it should be, this will cause the possibility of cancer appearing again, because the radiation dose is not distributed properly. So it can be stated that the use of 4 gantry angles is better than the use of 6 gantry angles when viewed from the PTV dose of 95% obtained when planning.

2. Comparative analysis of Conformity Index (CI) and Homogeneity Index (HI) values for PTV using 4 gantry angles and 6 gantry angles.

To compare good gantry angles, CI and HI parameters are used as a comparison where the Conformity Index (CI) or radiotherapy suitability index is useful for quantitatively assessing the quality of radiotherapy treatment plans, and represents the relationship between isodose distribution and target volume (Brennan, et al., 2010). The equation used is:

$$CI = \frac{V_{95\%}}{VPTV} \quad (1)$$

CI is the Conformity Index value, V_(95%) is the value of the cancer volume that receives a dose of 95% of the given dose, and VTPV is the volume of the PTV. Where the ideal value of CI is 1, the closer the value is to 1, the better (conformity) (Husni, et al., 2021). Comparison of CI values from the use of the two gantries can be seen in the table below.

Table 2. Cancer volume receiving 95% dose and CI values using 4 gantry angles and 6 gantry angles.

Patient	$V_{95\%}$ usage of 4 gantry corners (%)	Value CI usage of 4 gantry corners	$V_{95\%}$ usage of 6 gantry corners (%)	Value CI usage of 6 gantry corners
1	99,52%	0,9952	94,09%	0,9409
2	96%	0,96	84,11%	0,8411
3	99,15%	0,9915	97,8%	0,978
4	94,51%	0,9451	94,04%	0,9404

Patient	$V_{95\%}$ usage of 4 gantry corners (%)	Value CI usage of 4 gantry corners	$V_{95\%}$ usage of 6 gantry corners (%)	Value CI usage of 6 gantry corners
5	97,65%	0,9765	96,32%	0,9632
6	98,09%	0,9809	96,74%	0,9674
7	98,15%	0,9815	98,44%	0,9844

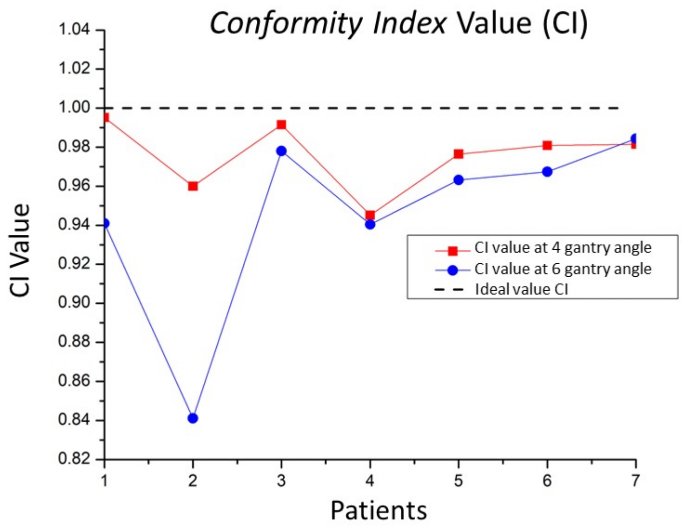

Fig 3. Comparison graph of CI values using 4 gantry angles and 6 gantry angles.

In Figure 3, this is a comparison of the CI value of the use of both gantries, as is known that the ideal value of CI is 1, so it can be seen that the value obtained by using 4 gantry angles is closer to 1 compared to using 6 gantry angles. So this states that the use of 4 gantry angles is better than the use of 6 gantry angles.

Then reviewed from the Homogeneity Index (HI) value. Where the Homogeneity Index (HI) or homogeneity index is useful for analyzing the uniformity of dose distribution in the target volume (Brennan, et al., 2010). The equation used is:

$$HI = \frac{D2\% - D98\%}{D50\%} \quad (2)$$

HI is the homogeneity index or uniformity of dose distribution in the target volume, D2% is the dose that covers 2% of the cancer volume, D50% is the dose that covers 50% of the cancer, and D98% is the dose that covers 98% of the cancer, where the ideal value of HI is 0, the closer to 0 the better (homogeneous) (Husni, et al., 2021).

A comparison of HI values from the use of the two gantries can be seen in the table below.

Table 3. HI values obtained from seven patients using 4 gantry angles.

Patient	**D2% (cGy)**	**D50% (cGy)**	**D98% (cGy)**	**HI value**
1	5270	5070	4830	0,08679
2	5240	5070	4670	0,12032
3	5320	5050	4820	0,0990
4	5290	5090	4180	0,21808

Patient	D2% (cGy)	D50% (cGy)	D98% (cGy)	HI value
5	5220	5050	4750	0,09306
6	5330	5110	4780	0,10763
7	5310	5080	4790	0,10236

Table 4. HI values obtained from seven patients using 6 gantry angles.

Patient	D2% (cGy)	D50% (cGy)	D98% (cGy)	HI value
1	5240	4980	4700	0,10843
2	5190	4980	4130	0,21285
3	5330	5090	4770	0,11002
4	5230	5050	4000	0,24356
5	5210	5040	4690	0,10318
6	5300	5060	4750	0,10870
7	5230	5060	4800	0,08498

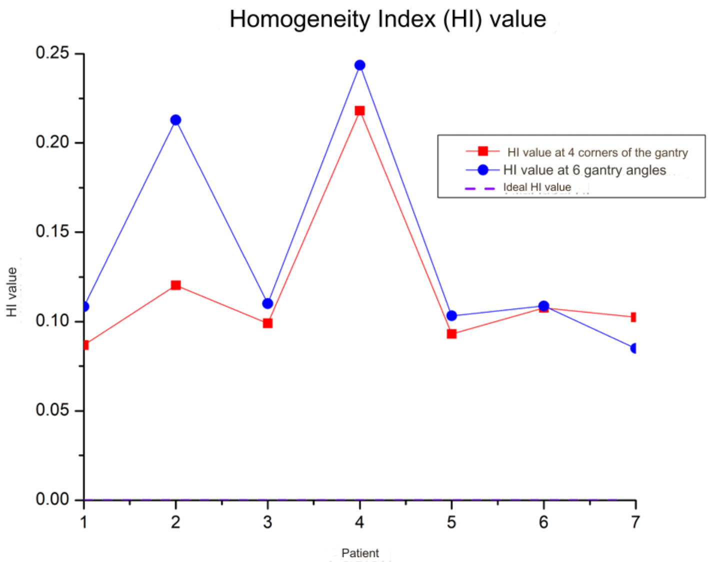

Fig 4. Comparison graph of HI values using 4 gantry angles and 6 gantry angles.

In Figure 4, this is a comparison graph of HI values obtained from seven patients using both gantry angles, as is known that the ideal value of HI is 0. So it can be seen in the graph that the use of 4 gantry angles from almost all patients is closer to the value of 0 compared to the use of 6 gantry angles. So it can be stated that the use of 4 gantry angles is better than the use of 6 gantry angles.

3. Measurement of the absorbed dose of radiation received by Organs At Risk (OAR) using 4 gantry angles and 6 gantry angles.

The results of the radiation absorption values received by the target volume in each organ vary based on the number of gantry angles used. Organs At Risk or Organs at Risk are normal tissues that are sensitive to radiation and greatly affect the dose given to patients, have a very low tolerance dose. Where the purpose of radiotherapy is to provide the specified dose to the target volume of cancer tissue and minimize it to adjacent tissue or OAR (Aisyah, et al., 2013). In this study, the values of 2 risk organs or OARs will be compared, namely the bladder and recti. A comparison of the OAR values obtained using 4 gantry angle planning and 6 gantry angles can be seen in the table below.

Table 5. Maximum dose to Organs At Risk (OAR) using 4 gantry angles and 6 gantry angles.

Patient	***Bladder* (6500 cGy)**		***Recti* (5000 cGy)**	
	4 *gantry corner*	6 *gantry corner*	4 *gantry corner*	6 *gantry corner*
1	5040	5040	4800	5080
2	5030	4980	4960	5090
3	5090	5120	4880	5210
4	5000	5060	4840	4950
5	5110	5110	4920	4940
6	5020	5130	4910	5280
7	5070	5110	4880	4980

Bladder is an organ located in the lower abdomen and is part of the urinary system. In planning cervical cancer radiation therapy, the maximum dose that the bladder can receive is 6500 cGy, so the lower the target volume received, the better. Then the recti is a channel in the digestive system that is the end of the large intestine, located at the end of the large intestine and ends in a short channel that leads to the anus. Where the maximum dose that the recti can receive is 5000 cGy.

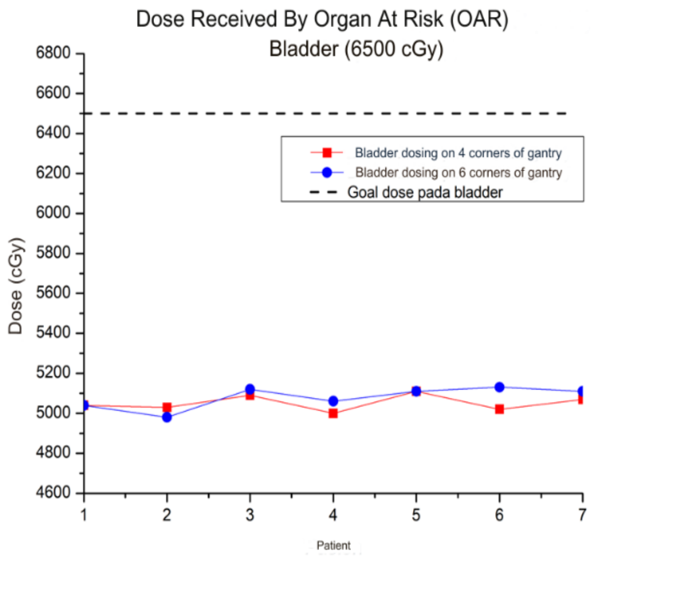

Fig 5. Dose graph received by the bladder from seven patients using 4 gantry angles and 6 gantry angles.

In Figure 5, which is a comparison of the dose values received by the bladder using both gantry angles, it can be seen that the use of both gantries is below the recommended maximum dose, but the value obtained using 4 gantry angles is lower than using 6 gantry angles, so it can be stated that the use of 4 gantry angles is better than the use of 6 gantry angles when viewed from the dose received by the bladder.

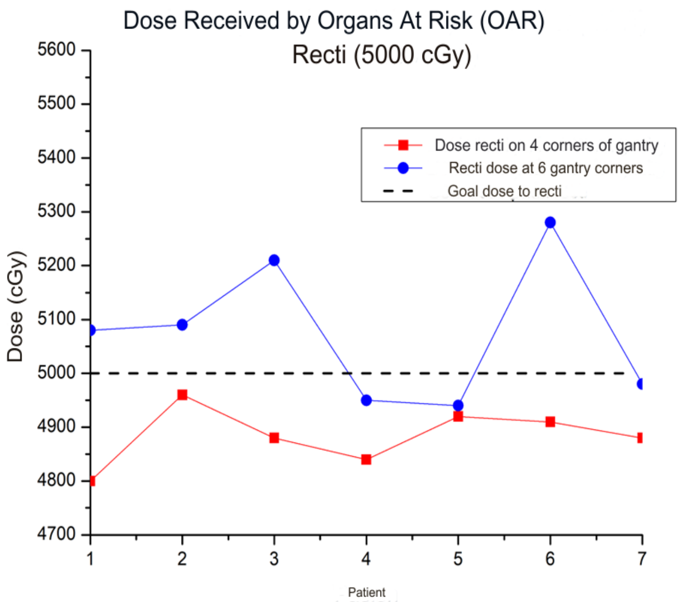

Fig 6. Dose graph received by the recti from seven patients using 4 gantry angles and 6 gantry angles.

in figure 6 where this is a comparison of the values received by recti using both gantry angles. it can be seen that some patients from the use of 6 gantry angles are above the maximum value that can be received by recti, while for the use of 4 gantry angles all patients are below the maximum value of recti. So, it can be stated that the use of 4 gantry angles is better than the use of 6 gantry angles when viewed from the dose received by recti.

4. Comparative analysis of isodose curves using 4 gantry angles and 6 gantry angles.

Isodose curve is to review the suitability of radiation therapy planning with the shape of the tumor, where the more the radiation beam approaches the shape of the tumor, the better. In the sense that the dose is evenly distributed in the cancer tissue and minimizes the dose received by the OAR.

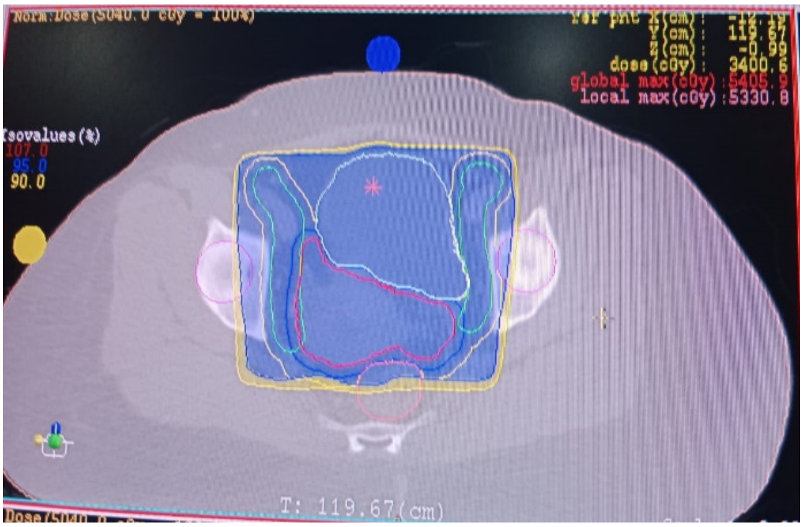

Fig 7. Isodose curve using 4 gantry angles

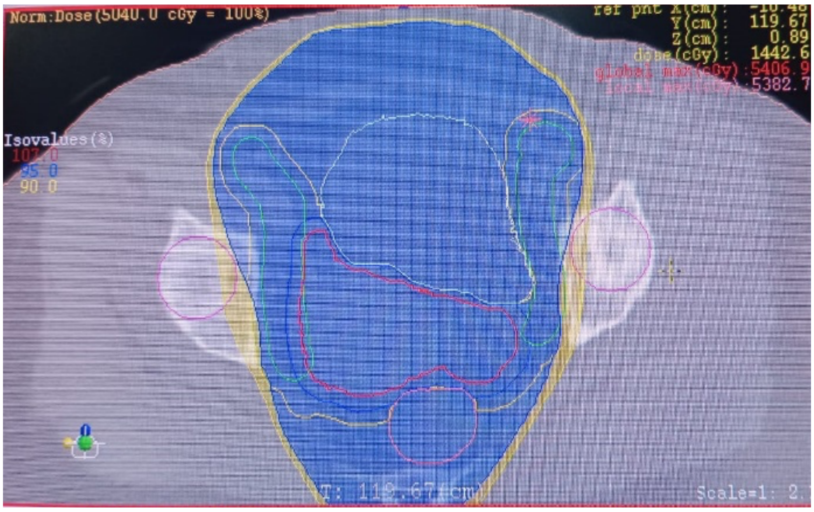

Fig 8. Isodose curve using 6 gantry angles

Figure 7 is an isodose curve using 4 gantry angles and figure 8 is an isodose curve using 6 gantry angles, where the red line is the tumor, the light blue line is the bladder, the pink line is the recti, the blue color that covers the organs is the 95% PTV volume and the yellow color is the 90% PTV volume.

It can be seen that the planning of radiation therapy using 4 gantry angles is closer to the tumor compared to the use of 6 gantry angles, this is due to the addition of angles of 40o, 220o, and 320o. This of course has an effect on the OAR where the upper part (intestinal part) which should not be exposed is exposed to radiation and the lower part of the bladder should also get a higher absorbed dose than it should, this also causes the OAR value obtained from the use of 6 gantry angles to be greater than the use of 4 gantry angles and this is very inefficient. So it can be stated that the use of 4 gantry angles is better than the use of 6 gantry angles when viewed from the isodose curve obtained.

IV. Conclusion

From the results of the study, it can be concluded that when viewed from the dose received by the target volume (max dose and PTV dose 95%), the suitability of the cancer volume receiving the dose (CI parameter) and the uniformity of the dose spread over the cancer volume (HI parameter), the dose received by the OAR and the shape of the isodose curve then the use of 4 gantry angles is better and more efficient than the use of 6 gantry angles. So, it can be concluded that the use of 4 gantry angles in the treatment planning system for cervical cancer is more efficient than the use of 6 gantry angles.

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