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Evaluation Target Volume and Distribution Organ at Risk in Rectal Cancer Using 3D-CRT Technique Based on QUANTEC

Fitria Istiqomah[1], Muhammad Irsal*[1], Shinta Gunawati Sutoro[1], Guntur Winarno[1], Samsun[1], I Gede Kesuma Wardana[2]

[1]Department of Diagnostic Imaging and Radiotherapy, Poltekkes Kemenkes Jakarta II, Jakarta, Indonesia.

[2]MRCCC Siloam Hospitals Semanggi, Jakarta, Indonesia.

*Corresponding author: muhammad.irsal@poltekkesjkt2.ac.id

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ABSTRACT

Background: The 3D-CRT technique in rectal cancer patients is a radiation therapy treatment to destroy cancer cells. The success of radiation therapy depends on the accuracy of the target volume dose and Organ At Risk (OAR). Therefore, when administering the dose, it is necessary to calculate it appropriately using QUANTEC to avoid toxicity. Objective: This study is to describe radiotherapy radiation, measurement of Planning Target Volume (PTV) V95% dose distribution and OAR, as well as a comparative analysis of PTV dose distribution against ICRU and OAR against QUANTEC guidelines. Method: The research used is a quantitative descriptive comparative evaluation. This research was conducted in the Department of Radiotherapy in Jakarta area from September to November 2023. The research was conducted on 20 rectal cancer patients using the 3D-CRT technique and data analysis was carried out using descriptive statistics. Result: The average dose value received by PTV V95% is 5133 or PTV V95% ≥ 4750. Meanwhile, the average dose received by the OAR bladder and femoral head exceeds QUANTEC criteria. This is because the cancer stage has metastasized, and the number of doses and fractions can also affect the dose received by the OAR.

Keywords : 3D-CRT Rectal Cancer, Organ at Risk (OAR), Planning Target Volume (PTV), QUANTEC.

I. INTRODUCTION

Radiotherapy, also known as radiation therapy, is a treatment that uses high-energy rays to destroy cancer cells. EBRT technique (Externa Beam Radiation Therapy) one of which is technique Three-Dimensional Conformal Radiation Therapy (3D-CRT), is an approach in radiotherapy in which planning and radiation dose administration is based on 3D image data. 3D imagery allows more accurate planning in determining the illumination field that suits the shape of the target. By using the 3D-CRT technique, the

radiation field is made according to the shape of the target, thereby maximizing the high radiation dose precisely to the target area while minimizing the radiation dose received by healthy organs [1].

At the CT Simulator stage carry out simulations and take images. The resulting image will be sent to the treatment Planning System (TPS) to carry out therapy planning. The TPS process is a systematic approach to therapy planning that includes determining the angle design gantry, number of radiation fields, radiation energy to be given, dosimetry, and dose distribution. The targets that are the focus of TPS are Planning Target Volume (PTV) and Organ At Risk (OAR) [2].

The radiotherapy process of the 3D-CRT technique requires precise determination of the location and shape of the clear target gross Tumor Volume (GTV), the area around the tumor that has the potential to be affected by cancer cells Clinical Target Volume (CTV), as well as areas that must be maximized in radiotherapy planning to ensure cancer cells are hit accurately and precisely Planning Target Volume (PTV). In addition, important organs around cancer or organs at risk must also be identified precisely to minimize the impact of radiation on healthy tissue [3].

Planning Target Volume (PTV) is the target volume of the cancer or tumor to be irradiated, the isodose curve must cover the entire PTV of the contour structure of the cancer organ being targeted. Dosimetry at a certain depth level will be influenced by the energy of the photons and electrons used [2][4]. Organ At Risk (OAR) is a tissue or organ that is susceptible to radiation, so the radiation dose received by these organs will have a significant effect if it exceeds its tolerance limit. Therefore, special planning needs to be carried out to protect organs at risk from radiation and prevent damaging effects on these organs [5].

In radiation therapy understanding the limits of dose and volume tolerance for organs at risk is very important to avoid the possibility of more severe toxicity. Several parameters have been set as tolerance limits, one of which is Quantitative Analyses of Normal Tissue Effects in the Clinic (QUANTEC) in 2010 [6]. The dose distribution for various organ volumes can be seen in the graph Dose Volume Histogram (DVH). The DVH graph is a histogram graph that relates radiation dose to organ volume in therapy planning. DVH functions as a 2D graph that depicts the distribution of doses in 3D in an organ [2][7].

Based on research by Hannisa Heryana Pratiwi (2015) looking at DVH in rectal cancer, the dose received by OAR (Bladder, Prostate, Small Bowel, Colostomi, seminal vesicles Femoral Head Right, Femoral Head Left and penile Bulb) differs between techniques Intensity-Modulated Radiation Therapy (IMRT) and volumetric Modulated Arc Therapy (VMAT). On the OAR Colostomi The radiation dose is higher in the IMRT technique compared to the VMAT technique. However, the average dose received by OAR using the IMRT technique is slightly lower compared to the VMAT technique [8].

Research conducted by Poojashree, K. S et al., (2022) The dose suitability of this study is based on or measured according to ICRU (International Commission on Radiation Unit and Measurement), and this type of research uses prospective studies (Cohort). The results of the analysis on the IMRT technique are superior to 3D-CRT inhomogeneous dose distribution of the target volume without reducing the average dose of PTV in the treatment of rectal cancer. The dose received by Organ At Risk (OAR) bowel (intestinal) in the IMRT technique is less than the 3D-CRT technique and the results of the analysis of the level of toxicity fall into the category grade 3 [9].

Therefore, the results above show that the 3D-CRT technique will provide a higher dose to the OAR and needs to be evaluated. So the author aims to conduct research evaluating the dose distribution in the target volume and OAR exposed to radiation in cases of rectal cancer using TPS calculations using the 3D-CRT technique. This research will use a prospective study (Cohort), but what differentiates this study is

the suitability of doses based on QUANTEC, PTV at 95% volume, and OAR (bladder and femoral head). Therefore, the background of this study is the interest in evaluating the dose distribution to the target volume and OAR in rectal cancer with the 3D-CRT technique based on QUANTEC.

II. METHODS AND MATERIAL

Research design

This research design is a type of comparative evaluation research that is descriptive and quantitative. The data that will be used is secondary data that will be taken from TPS in DVH format, this research will use a prospective study (Cohort). This research was carried out at in the Department of Radiotherapy in Jakarta area with the research period being carried out from September to November 2023.

Data collection

Data was collected by collecting secondary data on patients who underwent radiotherapy using the 3D-CRT technique, after which the data was grouped based on gender, age, clinical examination, and the technique used. The method for calculating the number of research samples uses the Slovin formula. This formula is used to determine the minimum sample size from a population by considering specified errors. The number of people in a population is represented by N, and the margin The established error is represented by (e), which is usually expressed as 0.05 to 5%. This calculation aims to obtain a minimum research sample size (n) that can represent the population with a certain error rate. The Slovin formula for calculating the research sample size is as follows [10]:

$$n = \frac{N}{1 + N(e)^2}$$

If the number of people in the population (N) is 21 and the specified margin of error (e) is 0.05 (or 5%), then you can calculate the minimum research sample size (n) as follows:

$$n = \frac{21}{1 + 21(0{,}05)^2} = \frac{21}{1 + 21\ (0{,}0025)} = 19{,}95$$

For this research, the minimum sample size required is around 20 people to represent the population with an error rate of 5%. Because the sample size must be an integer, it is 20 samples.

Statistical analysis

After collecting data, descriptive statistics were carried out to provide a general description of the characteristics of this research sample: average, standard deviation, minimum, maximum, and median. The test used to test PTV and OAR, the data from this evaluation will then be compared with the tolerance limits set based on QUANTEC, to evaluate the extent to which the data results from the 3D-CRT technique match the established standards.

III. RESULTS AND DISCUSSION

From the results Planning Treatment System (TPS) using the 3D-CRT external radiation technique in patients with clinical rectal cancer at the Department of Radiotherapy in the Jakarta area, obtaining a total of 20 samples. The total dose of radiation given was 50_{Gy} (5000 cGy) given in 25 fractionations with a radiation energy of 6 MV.

TABLE 1. Data Characteristics

Data	Total	Percentage (%)	Range
Gender			
Man	5	25	-
Female	15	75	-
Age			
<50 years	4	20	23-50
>50 years	16	80	51-72

Based on the results of observations at the department of radiotherapy, which was carried out by collecting

secondary data from 2021 to June 2023, a total of 20 patient samples were obtained in cases of rectal cancer using the 3D-CRT technique as shown in Table 1 It is known that the number of male samples is five samples or 25%, while the number of female samples is 15 samples or 75%, while the data for the age group under 50 (23-50) years has four samples or 20% and the age group over 50 (51-72) years as many as 16 samples or 80%. Table 2. Shows descriptive statistical results of PTV and OAR.

Based on the comparison results Table 3. The average PTV was 5133.35 cGy which was compared with the ICRU recommendation for a minimum dose affected by a PTV volume of 95% ≥ 4750 cGy. For OAR bladder got an average result of 74.50, based on Softa V research, et al., namely 47.79 with a difference value of 55.89% and research by Aynaci O, et al., The average result obtained was 57.22 with a difference value of 30.19%. On OAR femoral head left got an average score of 52.25 in the Softa V research, et al., namely 42.45 with a difference value of 23.08% while in research by Aynaci O, et al., The average result obtained is 25.16 with a difference value of 107% and OAR femoral head right got an average score of 46.85 in the Softa V research, et al., namely 42.45 with a difference value of 10.36% and in research Aynaci O, et al.,27.59 with a difference value of 69.80%.

At the Department of Radiotherapy, in carrying out the 3D-CRT technique procedure on rectal cancer patients, radiotherapists prepare the tools and materials needed for the simulation process and during radiation, such as immobilization equipment and every radiation in the pelvis usually uses a bladder protocol (full blast) to get a consistent urine volume in ladder every time it is illuminated. The TPS planning process was carried out by a medical physicist and approved by a radiation oncologist. The radiation field used was a field withbox system and the radiation dose given is 50Gy with 25 fractionations given 5 times a week. Every multiple of 5 times the radiation to carry out blood tests and consult a radiation oncologist, this radiation exposure is following the theoretical basis.

For decades the 3D-CRT technique has been one of the main treatments in radiotherapy, providing high dose levels using radiation to target the desired area. This method also provides higher protection against OAR compared to previous 2D techniques [11]. The choice of radiotherapy technique for rectal cancer has a very-

TABLE 2. Descriptive Statistics

Value	PTV V95%	Bladder V50 Gy	Femoral Head Left V44 Gy	Femoral Head Right V44 Gy
N	20	20	20	20
Range	1183	89	100	99
Minimum	4920	11	0	0
Maksimum	6103	100	100	99
Sum	102667	1490	1045	937
Mean	5133.35	74.50	52.25	46.85
Std. Deviation	252.914	27.510	43.884	40.193
Variance	63965.503	756.789	1925.776	1615.503
Skewness	3.364	-.867	-.338	-.205
Kurtosis	12.376	-.378	-1.957	-1.865

TABLE 3. Comparison Results of 3D-CRT Techniques

Organ	This research, 50 Gy, 25 Fractions	ICRU 95%	Study Softa V, *et al.*, 50.4 Gy, 28 Fractions		Study *Aynaci O, et al.*, 78 Gy, 39 Fractions	
			Value	Diff (%)	Value	Diff (%)
PTV	5133.35	≥ 4750	-	-	-	-
Bladder	74.50	-	47.79	55.89	57.22	30.19
Femoral Head L	52.25	-	42.45	23.08	25.16	107
Femoral Head R	46.85	-	42.45	10.36	27.59	69.80

important impact on optimal results with one effective option being the 3D-CRT technique. This technique aims to provide a high dose rate to the target volume while simultaneously reducing the dose to the surrounding healthy tissue. Based on research in the field of radiobiology, it has been proven that the 3D-CRT technique is successful in treating stage T1-3N+M0 rectal cancer with preoperative radiotherapy. The 3D-CRT technique provides better coverage of the target volume although the IMRT and VMAT techniques are more homogeneous in dose coverage to the target [12].

Planning Target Volume (PTV) is a geometric concept used in radiotherapy planning to precisely determine the volume that must be irradiated, considering all possible geometric variations. The goal is to ensure that all cancer cells receive the radiation dose as planned [13]. Planning on PTV is used to determine all cancers and margins by ensuring that all cancer cells will receive the required target dose according to the guidelines of the International Commission on Radiation Units and Measurements (ICRU). The dose that must be given to PTV is at least 95% of the total dose given. In this study, the radiation dose used was 50 Gy (5000 cGy) was determined as the total dose desired to achieve a therapeutic effect on PTV of rectal cancer using the 3D-CRT technique. Providing an accurate dose to PTV, to ensure that all cancer cells receive the radiation dose according to ICRU recommendations in the hope of achieving optimal results.

Organ At Risk (OAR) is a healthy organ that has a high sensitivity to radiation and is susceptible to damage if exposed to radiation. When planning radiotherapy, radiation exposure to the OAR must be minimized to reduce the risk of side effects and complications in patients [4]. In radiation exposure for rectal cancer, determining tolerance for OAR can be seen based on the QUANTEC and RTOG 0822 guidelines in both neoadjuvant and adjuvant settings, OAR for rectal cancer usually includes small bowel, bladder, and femoral head [14]. Accuracy in administering the radiation dose is very important considering the healthy organs around it. TPS will produce DVH which is the most important part of planning radiation exposure. DVH is used to analyze and describe the distribution of radiation doses that will be received by PTV and OAR that are exposed to radiation during radiation exposure.

Based on QUANTEC's tolerance limits the bladder with a dose of V65 Gy < 50%, which means the bladder that receives a volume dose of 65 Gy cannot exceed the percentage of 50% and the femoral head at V44 Gy < 5%, which is the significant femoral head who receives a volume dose of 44 Gy should not exceed a percentage of 5%. [15]. The comparison results for this study show PTV 95% ≥ 4750 following ICRU guidelines, for OAR bladder, femoral head left and right greater than the tolerance limits of QUANTEC and Softa V research, et al., and research Aynaci O, et al., which is written on Table 3. In the first research conducted by Softa V, et al., using the

3D-CRT technique with a dose of 50.4 Gy in 28 fractions, the amount of data used was 24 stage T1-3 patients without M0 metastases and with N+ positive lymph node locally advanced rectal cancer undergoing neoadjuvant chemoradiation therapy. Results from research on OAR Bladder average value 47.79, Femoral Head This mean value of 42.45 shows that the 3D-CRT technique is successful in treating stage T1-3N+M0 rectal cancer with preoperative radiotherapy [12]. The second research conducted by Aynaci O, et al.,3D-CRT technique using a determined dose of 78 Gy with 39 fractions divided into 2 PTV parts. Where the PTV-1 portion of the dose given is 56 Gy with 28 fractions and the PTV-2 dose of 22 Gy with 11 fractions. The amount of data used was 14 patients for the results of the dose received by OAR to obtain the average value of 57.22%, Femoral Head Left 25.16, and Femoral Head Right 27.59. The 3D-CRT technique is compared with other techniques (p-value 0,03 and 0.00) there is no significant difference between existing techniques [16].

This research is different from the research listed in Table 3. has been explained due to the administration of the total dose and its fractions, this occurs because it considers the administration of the dose according to a particular stage. According to the National Guidelines for Medical Services for the Management of Colorectal Cancer in T3N0-1 PTV cases (standard risk) the dose given was 45 Gy with 1.8 Gy/fraction, while for PTV (high risk) of 50 Gy with 2 Gy/fraction. For the case of T4N0-1 PTV (standard risk) a determined dose of 45.9 Gy with 1.7 Gy/fraction, at PTV (high risk) the dose is 54 Gy with 2 Gy/fraction. Meanwhile, the post-operative radiation dose ranges from 45-60 Gy with fractions of 5 x 200 cGy. In cases with limits margin positive the dose given ranges from 54-60 Gy [17]. The difference in the number of doses and fractions can influence the dose received by the OAR radiobiological. Radiobiology considers tissue and organ response to radiation and a significant factor is determined by dose fractionation. With many fractions, the total dose administered can be determined to minimize the dose received at OAR. Decisions about the number of fractions in radiation therapy are usually based on the clinical and radiobiological characteristics of the patient as well as the cancer type or stage [18]. The percentage difference between this research and previous research also shows significant Risk (OAR) bladder at 55.89% and 30.19%, respectively femoral head left at 23.08% and 107%, as well as at femoral head right at 10.36% and 69.80%.

From the results of interviews with medical physicists, it was found that considerations in administering radiation doses for rectal cancer using the 3D-CRT technique depend on the stage of the cancer suffered by the patient. The stage determines how serious the cancer is, usually from the shape, and condition of the gland or indications of safe glands, to the presence of metastases. From the results of this research data, it was found that OAR exceeded QUANTEC's tolerance limit because the cancer had metastasized. So the dosage is adjusted to the severity of the stage, and the guidelines used vary depending on the doctor's decision. Some doctors may choose certain guidelines when they are not included in the definition. They will determine the guidelines that will be used, not only determine which guideline should be used as a reference, and also consider the patient's condition. For administering the total dose and the fraction given, the number of doses received can be influenced by the volume percentage. For example, the dose of 50 Gy 25 fractions and 60 Gy 30 fractions of the dose affected by the volume percentage is different, but for the picture, there is no relationship depending on the type of tumor and cells.

Limitations in this study are the lack of data regarding the stage of rectal cancer patients, the lack of comparative research with normal Tissue Complication Probability (NTCP), and the limitations of QUANTEC guidelines for rectal cancer using a dose of 50 Gy with the 3D-CRT technique. In addition, the dosage and techniques used for rectal cancer patients

vary according to individual treatment needs. This research also does not discuss OAR bowel (intestinal) and other OARs so the evaluation of dose distribution is only limited to OARs bladder, femoral head left and right. In the future, it is recommended to develop comparative research with NTCP, so that we can determine the possibility of complications occurring in normal tissue receiving radiation during the radiotherapy process and measure the risk of side effects or damage to organs around the irradiated area.

IV. CONCLUSION

The results of data from 20 rectal cancer patients using the 3DCRT technique show that the majority of data are from women aged over 50 years. The results of descriptive statistics for dose for PTV are 95% (5133.35 ± 252,914) and Organ At Risk (OAR) bladder $V50_{Gy}$ (74.50±27.510), femoral head left $V44_{Gy}$ (52.25±43.884), and femoral head right $V44_{Gy}$ (46.85±40.193). Next from the results planning data on 20 rectal cancer patients using the 3DCRT technique, the dose received by planning Target Volume (PTV) V95% ≥ 4750 cGy, while dose Organ At Risk (OAR) bladder exceeds the QUANTEC criteria limit (<50%), and femoral head obtained dose distribution results that exceeded the QUANTEC criteria (<5%). This is because the cancer has metastasized and the number of doses and fractions can affect the dose received by the OAR.

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