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Comparison of Photon Dose Distribution in Breast Cancer Using 3DCRT and Half Beam Techniques

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ABSTRACT

Radiotherapy planning can be done with 3D Conformal Radiotherapy (3DCRT) and Half Beam. The success of radiotherapy planning is considered by comparing the isodose curve, Dose Volume Histogram (DVH), Organs at Risk (OAR), Homogeneity Index (HI), and Conformity Index (CI) obtained by the 3DCRT and Half Beam techniques. This study used data from 5 patients at the Radiotherapy Installation at A.W. Hospital. Sjahranie Samarinda with radiation planning of 5000 cGy (25×2 Gy) for breast cancer. The two radiation plans used gantry angles of 310˚ and 120˚. The calculated dose distribution value can be seen through the 90%, 95% PTV dose, and OAR absorbed dose. PTV doses of 90% and 95% in the 3DCRT technique covered the target well. The radiation dose values of the 3DCRT technique at PTV 90% were around 4860 cGy – 4930 cGy and PTV 95% were around 4750 cGy – 4840 cGy. Meanwhile, the Half Beam technique could not cover the target well. It was because the radiation dose values received by the Half Beam technique at 90% PTV were around 780 cGy – 4860 cGy and 95% PTV were around 2210 cGy – 5020 cGy. The OAR absorbed doses values for the 3DCRT and Half Beam techniques were still within the safe limits of tolerance according to QUANTEC. Meanwhile, the HI and CI values in the 3DCRT technique were closer to the rules of ICRU Report 83 of 2010 compared to the Half Beam technique. Therefore, from the values that have been obtained, the success rate of the radiotherapy planning process after measurements is shown in the 3DCRT technique. It has the value of more efficient dose calculations and can be used as a reference in optimizing dose distribution to patients.

I. Introduction

Radiotherapy is one of the latest cancer treatment technologies, which provides a measured dose of radiation by calculating the dose distribution that will be given to the patient. Radiotherapy is one of the cancer therapy modalities besides surgery and chemotherapy. The goal of radiotherapy is to deliver the maximum possible radiation dose to the target/cancer area and the minimum possible radiation dose to organs at risk. One of the radiotherapy modalities with external radiation source is Linear Accelerator (Linac) [1]. Linac is an instrument that produces high-energy electrons or photons. High-energy electrons are used to treat cancer or tumors that are superficially positioned (skin surface), while high-energy photon beams to treat cancer that is located deeper [2]. The Linac therapy aircraft at RSUD A.W. Sjahranie Samarinda has two irradiation techniques used for breast

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cancer treatment, namely Three Dimension Conformal Radiotherapy (3DCRT) and Half Beam. The 3DCRT technique is a depiction of the process of planning and providing radiotherapy on three-dimensional and conformal imaging data which is a form of irradiation that is adjusted to the shape of the radiation target [3]. Half beam technique is a technique used in maintaining optical structures that have a tolerance value much lower than the tumor target. Half Beam technique is also called half-field irradiation technique or monoisocentric technique. This half-field irradiation technique was developed to overcome the nonhomogeneous dose in hot spots [4].

The thing that must be considered before irradiating the target is to carry out the planning process for giving radiation doses to patients called the Treatment Planning System (TPS). TPS is a combination of hardware and software components used to generate and display dose distribution calculations for medical physicists who determine patient radiation irradiation [5]. TPS has two irradiation targets, namely Planning Target Volume (PTV) which is the main target of irradiation and Organ At Risk (OAR) as the second target which is a healthy organ that must be protected around the main target and is sensitive to radiation exposure [6]. TPS is used to determine radiation energy, field area, number of radiation fields, irradiation direction, and MU calculation. Radiotherapy planning is individualized for each patient to be treated [7]. Some parameters that can be evaluated in the calculation of dose distribution and the success rate of radiotherapy planning can be seen from the isodosis curve, the value of dose homogeneity or Homogeneity Index (HI), and the value of dose distribution conformity or Conformity Index (CI) based on Dose Voleme Histogram (DVH).

Research to determine the photon beam profile in half-field irradiation (half beam) with a wedge that can overcome radiotherapy challenges for sino-nasal tumors [4]. Furthermore, research has been conducted to evaluate the results of TPS simulation of 3DCRT techniques in breast cancer cases to comply with the standards permitted by the International Commission on Radiation Units and Measurement (ICRU) [5]. Research to compare treatment planning results using two different techniques, namely 3DCRT and IMRT techniques for three cases of post-mastectomy left breast cancer [8]. Then, research was conducted on the comparison of the two techniques to analyze dose distribution in cervical cases through the Conformity Index (CI) and Homogeneity Index (HI) and OAR (Organ At Risk) which only focused on the bladder and rectum organs [6, 9].

Based on information from previous studies, the researcher was inspired and made previous research as a reference, so the researcher conducted a study to compare the calculation of photon dose distribution using two different techniques for a more specific type of cancer, namely left breast cancer. The techniques used are 3DCRT and Half Beam. This was done to see the results of a more efficient dose calculation for the two techniques, in order to minimize the radiation received by the patient. Therefore, this study was conducted with the aim of comparing the results of the isodosis curve and Dose Volume Histogram (DVH) to the dose distribution to be given to the patient. Furthermore, it analyzes the value of Homogeneity Index (HI) and Conformity Index (CI). The research was conducted at Radiotherapy Installation of RSUD A.W. Sjahranie Samarinda.

II. Method

The data collection technique is carried out when patient data is sent to the Medical Physicist computer for the planning process. The several stages carried out for data collection in this study used secondary data in the form of CT Simulator images of five breast cancer patients at the Radiotherapy Installation of RSUD A.W. Sjahranie Samarinda in 2019-2023. This irradiation planning was carried out using two techniques, namely 3DCRT technique and Half Beam technique using XiO computer software on Linac ELEKTA for left breast cancer cases. The research variable used is the difference in isocenter points of the two techniques. The photon energy beam used was 6 MV with a prescribe dose of 5000 cGy (25 × 2 Gy), irradiation angle (gantry) of 310˚ and 120 ˚ and the use of Multileaf Collimator (MLC) and fixed jaws.

In the Half Beam technique, the first thing to do is to determine the location of the isocenter point. This isocenter is placed at the boundary between the tumor and nodes. After determining the isocenter point, two parts of the field are made, namely between the upper field (nodes) and the lower field (tumor) with a predetermined tangential angle. Meanwhile, the 3DCRT technique is performed without the Half Beam (half field), that is, the point is made without dividing the two parts, but in this technique direct planning is carried out between the nodes and the tumor with the same tangential angle.

After the two planning processes using two techniques, the isodose curve and DVH graph are obtained. The TPS process calculates the dose of each point on the patient's body. The points with the same dose are connected and form a curve called the isodosis curve [10]. This isodosis curve is a curve shape that connects the same doses to the depth and width of the radiation field on the phantom and patient. The isodosis curve can be used to see the radiation dose distribution on the target cancer volume as well as on the surrounding at-risk organs [11]. Meanwhile, the DVH graph is a histogram graph that shows the relationship between volume, both target volume and OAR with radiation dose in the form of x and y axes. The x-axis shows the amount of radiation dose received in units of cGy, while the y-axis shows the percentage of normal volume of both the target volume and OAR [6].

The results obtained from the isodose and DVH curves were checked. Checking the value is seen in the results of calculating the dose distribution at the PTV 90%, PTV 95%, and global max values that have met the requirements of the dose that must be received by the target and the absorbed dose value received by the organ at risk (OAR) must be in accordance with the QUANTEC standard. The use of QUANTEC serves to determine the maximum dose threshold or the safe limit of tolerance allowed by OAR. The global max value is the overall value received by the target and OAR. If the global max value obtained has a large dose value, this indicates an area that receives excess radiation or is called a hostpot.

Evaluation of radiation planning results is carried out on several aspects, namely the conformity of the dose distribution to the target shape, the homogeneity of the dose in the target volume and the dose to the organs at risk near the target. Comparing the two techniques can be done by evaluating the dose distribution from the DVH graph on the Homogeneity Index (HI) and Conformity Index (CI) values. HI and CI values refer to ICRU Report 83 in 2010 [12], to find the HI value, a mathematical calculation is carried out in (1):

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}} \tag{1}$$

Uniformity of dose distribution within the target volume. HI is affected by the minimum dose, maximum dose, and average dose at the target. $D_{2\%}$ is the dose rate at 2% PTV volume (cGy), $D_{98\%}$ is the dose rate at 98% PTV volume (cGy), and $D_{50\%}$ is the dose rate at 50% PTV volume (cGy) [6]. Furthermore, looking for the CI value, the mathematical calculation is carried out in (2):

$$CI = \frac{V_{95\%}}{V_{PTV}} \tag{2}$$

The suitability of dose distribution to the tumor target is determined by the CI value which is the degree of suitability of the prescribed dose to cover the tumor target. $V_{95\%}$ is the volume that received 95% dose (cc) and V_{PTV} is the volume of PTV in the radiation target (cc) [6].

The data obtained through data collection will be subjected to a data analysis process. The data analysis technique carried out, namely by collecting data on the results of dose distribution that has been obtained by each technique in the form of 90% PTV dose value, 95% PTV, OAR absorbed dose (heart, right lung, and left lung), global max, and HI and CI values. The values obtained will be compared to determine the difference in the calculated value of a more efficient dose distribution in order to minimise the radiation received by patients from the two techniques.

III. Results and Discussion

The results in this study are the results of dose distribution calculations obtained based on the PTV 90% and PTV 95% values (the dose value that must be given to the target), the global max value (the overall dose value that the patient will receive in the form of dose values from the target and OAR), and the OAR absorbed dose value (the dose value received by the organ at risk and must comply with the QUANTEC standard as a safe tolerance limit allowed by OAR). The values obtained by both techniques can be seen in Table 1 and Table 2 below:

Table 1. PTV Dose Distribution in 3DCRT Technique

Patient	PTV 5000 (cGy)		OAR (cGy)			*Global Max* (cGy)
	90%	95%	*R. Lung*	*L. Lung*	*Cor*	
1	4870	4750	266	2683	2585	5575,5
2	4880	4770	-	1645	690	5762
3	4860	4770	187	2659	2415	5835,5
4	4880	4820	114	1944	1742	5812,5
5	4930	4840	-	1759	2173	5688

Table 2. PTV Dose Distribution in Half Beam Technique

Patient	PTV 5000 (cGy)		OAR (cGy)			*Global Max* (cGy)
	90%	95%	*R. Lung*	*L. Lung*	*Cor*	
1	4900	4730	275	1782	1467	6185,1
2	4680	4430	-	1198	343	5790
3	2210	780	143	2040	1189	5919
4	5020	4860	52	1452	1428	5796
5	4990	4750	-	1904	1762	5918

This calculation comparison is done to see the results of a more efficient dose value between the 3DCRT and Half Beam techniques. Figure 1, Figure 2, and Figure 3 show a comparison of the dose distribution of the PTV 90% , PTV 95%, and global max dose values using the 3DCRT technique and the Half Beam technique.

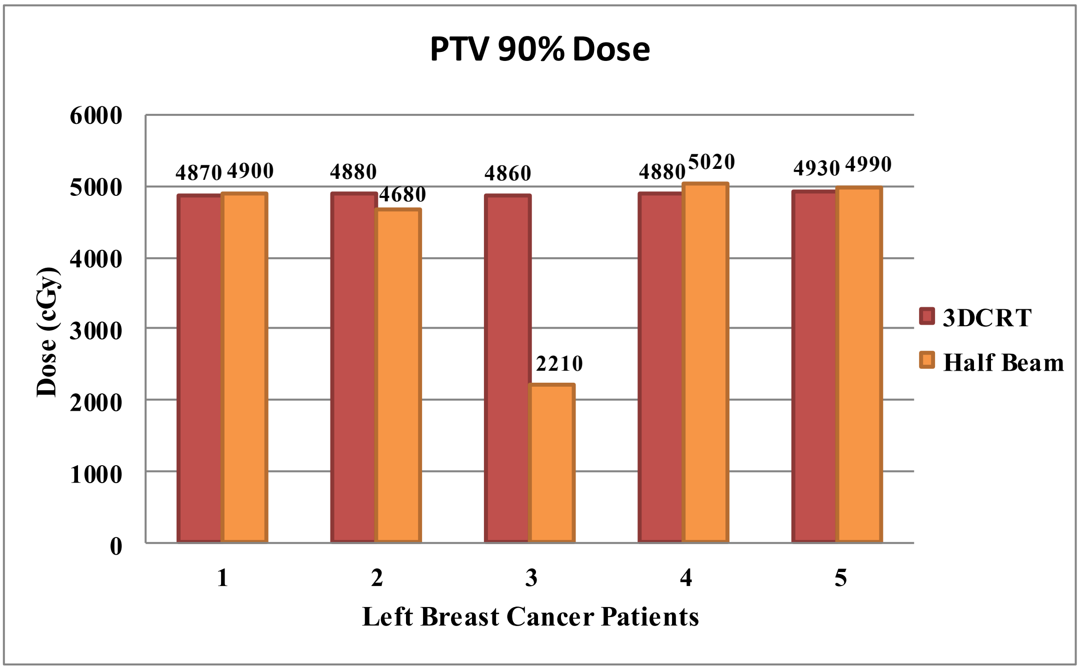

Fig. 1. PTV 90% Dose Comparison

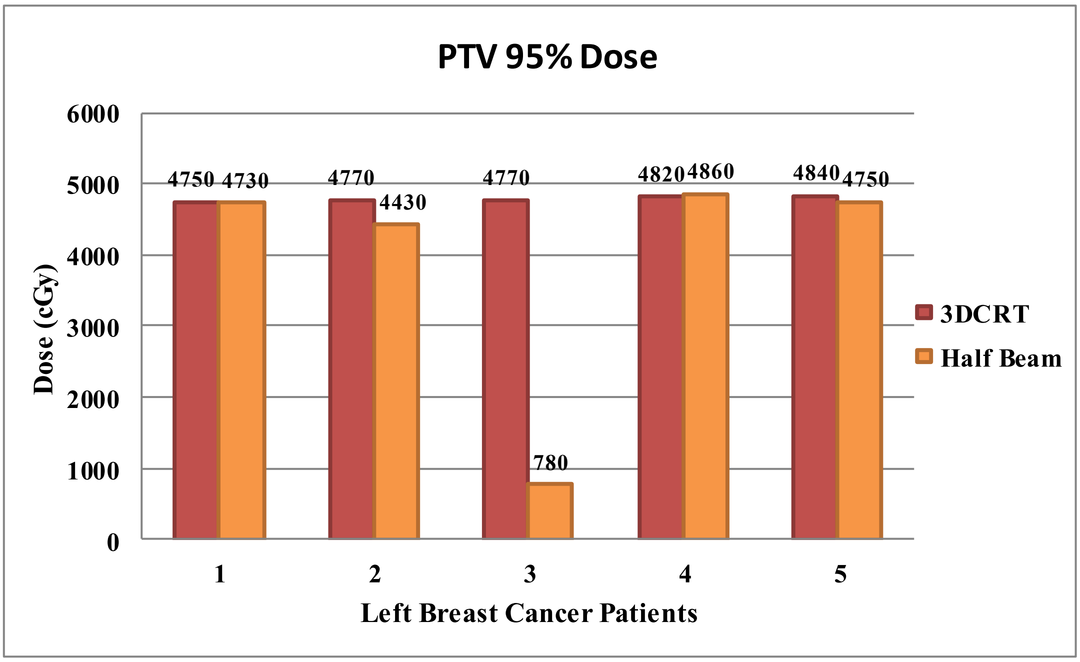

Fig. 2. PTV 95% Dose Comparison

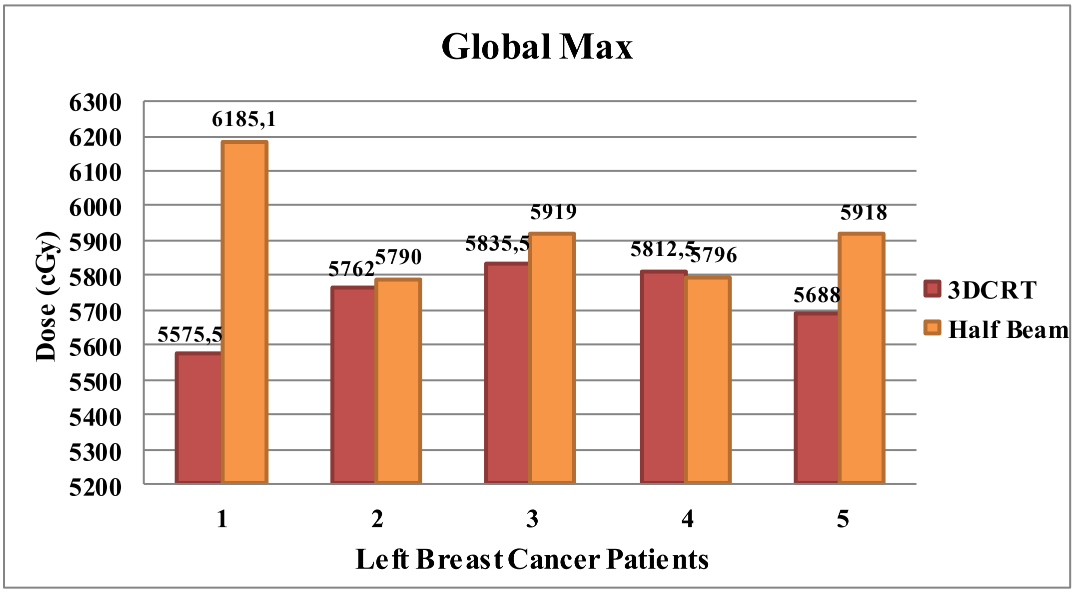

Fig. 3. Global Max Value Comparison

Figure 1 shows a comparison of the PTV 90% dose values of five left breast cancer patients. The orange graph is the dose value received by the target at 90% using the 3DCRT technique, while the yellow graph is the Half Beam technique. The minimum PTV 90% dose that the target should receive is 4500 cGy. The results obtained show that the 3DCRT technique has met the minimum dose requirement at PTV 90%, while in the Half Beam technique patient 3 does not meet the PTV 90% dose requirement. This is because patient 3 has a fairly long tumor shape, so that when the Half Beam technique is performed it results in an area covered by the field used to protect risky organs from being exposed to excess radiation. Meanwhile, the dose results obtained by patients 1, 2, 4, and 5 in the Half Beam technique have met the requirements, but the calculated dose value obtained is higher than the 3DCRT technique.

Figure 2 shows a comparison of the PTV 95% dose values of the five left breast cancer patients. The results obtained from both techniques show that the 95% PTV dose received by the target in the Half Beam technique does not meet the requirements and objectives of radiotherapy. This is because the minimum value of PTV 95% dose that must be given to the target is 4750 cGy. In the Half Beam technique, the PTV 95% dose that has met the minimum dose requirement is only in patients 4 and 5, with the dose of patient 4 amounting to 4860 cGy and patient 5 amounting to 4750 cGy, while in patients 1, 2, and 3 it does not meet the requirements because the dose value received by the target is <4750 cGy. Meanwhile, the five patients using the 3DCRT technique have met the requirements of the PTV 95% . If in the process of giving dose to the target does not meet the specified requirements, then this affects the dose to be given, resulting in the goal of radiotherapy not being achieved, which is to provide the maximum possible dose to the target and the minimum possible dose to risky tissues.

Figure 3 shows a comparison of the overall dose/global max values of the five patients. The results obtained show that the dose value in the 3DCRT technique is lower than the Half Beam technique, where the 3DCRT technique obtained a global max value in the range of 5575,5 cGy to 5835,5 cGy. Meanwhile, the Half Beam technique obtained global max values ranging from 5790 cGy to 6185,1 cGy. Therefore, from the global max values obtained, the 3DCRT technique has a better dose to minimize the radiation received by patients by maximizing the target dose and minimizing excess dose to the OAR than the Half Beam technique. This is because the global max value of the Half Beam technique obtained in patient 1 is 6185,1 cGy which indicates that the radiation dose received by the patient is quite large and should be reconsidered to Dr. Radiotherapy Specialist.

Organs At Risk (OAR) in breast cancer cases consist of the lungs and heart. In this case there are three parts of the organ that must be protected, including the right lung, left lung and heart. The OAR value obtained must be in accordance with the QUANTEC standard of each organ. Comparison of dose distribution to OAR can be seen in the DVH graph that has been obtained. Comparison of OAR absorbed dose values using 3DCRT and Half Beam techniques is shown in Figure 4.

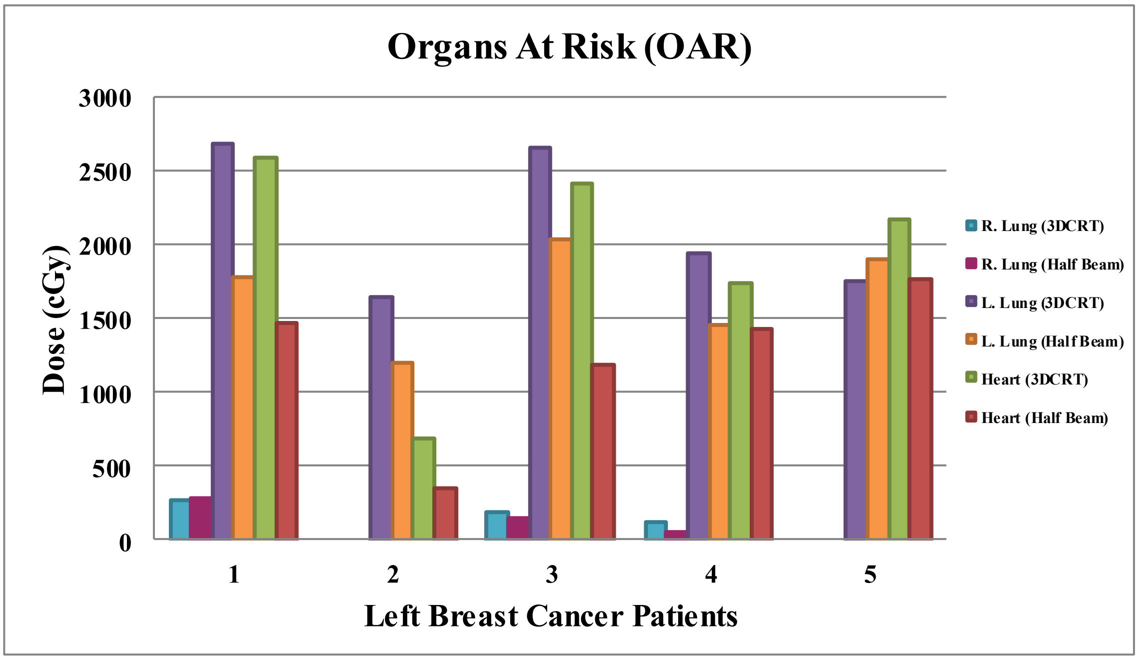

Fig. 4. Organ At Risk (OAR) Value Comparison

Figure 4 shows a comparison of OAR values in breast cancer cases. In the right lung, it shows that patients 2 and 5 have no radiation dose because these two patients have the same case, where the shape of the tumor is not too large so it does not spread to the right lung organs, causing the radiation dose value received by the right lung to be much lower. Comparison of OAR values in the right lung shows that the Half Beam technique for patients 3 and 4 has a lower value than the

3DCRT technique, but both techniques produce values that are still within the safe tolerance limits based on QUANTEC. Furthermore, the value of radiation dose received in the left lung OAR from both techniques is also still within the safe limits allowed by QUANTEC. The 3DCRT technique received a dose in the range of 1645 cGy to 2683 cGy and the Half Beam technique was in the range of 1198 cGy to 2040 cGy. The difference in radiation dose values received by the right lung and left lung indicates that the cancer is located in the left breast, so the left lung receives a higher dose.

Meanwhile, the heart OAR for the 3DCRT technique has a higher radiation dose value with a range of 690 cGy to 2585 cGy. Meanwhile, the Half Beam technique has a lower radiation dose value with a range of 343 cGy to 1762 cGy. Although the value of radiation dose received by organs in the 3DCRT technique is much higher than the Half Beam technique, both techniques are still within the safe limits allowed by QUANTEC. It can be concluded from the comparison of the dose distribution obtained, that good planning can be seen based on the dose value that has met the PTV requirements and the resulting OAR value must be in accordance with QUANTEC standards. The results of the comparison of the two techniques show that the 3DCRT technique has met the requirements by providing the target dose and the OAR value that is still within the tolerance limit, while in the Half Beam technique only the OAR value is in accordance with the QUANTEC standard, but the PTV requirements that must be given to the target are not met.

In the distribution of doses, an evaluation is needed to determine the success rate of the planning process. HI value is needed to determine the level of uniformity of dose distribution that will be received by patients [6]. The data needed to calculate the HI value is the radiation dose value at 2%, 50%, and 98% of the target volume. After the radiation dose value is obtained, a systematic calculation (1) is carried out to obtain the HI value. Table 3 shows the results of calculating the HI value in the five patients using 3DCRT and Half Beam techniques.

Table 3. HI values for 3DCRT and Half Beam Techniques

Patient	3DCRT				Half Beam			
	$D_{2\%}$ (cGy)	$D_{98\%}$ (cGy)	$D_{50\%}$ (cGy)	HI	$D_{2\%}$ (cGy)	$D_{98\%}$ (cGy)	$D_{50\%}$ (cGy)	HI
1	5450	4420	5170	0,20	5040	4500	5250	0,10
2	5600	4370	5250	0,23	5400	4030	5030	0,27
3	5570	4540	5220	0,20	5660	400	5130	1,03
4	5380	4750	5110	0,12	5690	4420	5330	0,24
5	5510	4690	5200	0,16	5750	4490	5260	0,24

Based on the results shown in Table 3, the HI value for the 3DCRT technique is between 0,12 and 0,23, while the HI value for the Half Beam technique is between 0,10 and 1,03. The ideal value of HI is 0 which indicates that the dose received by the target is homogeneous [12]. A comparison of the HI values for the 3DCRT and Half Beam techniques is shown in Figure 5.

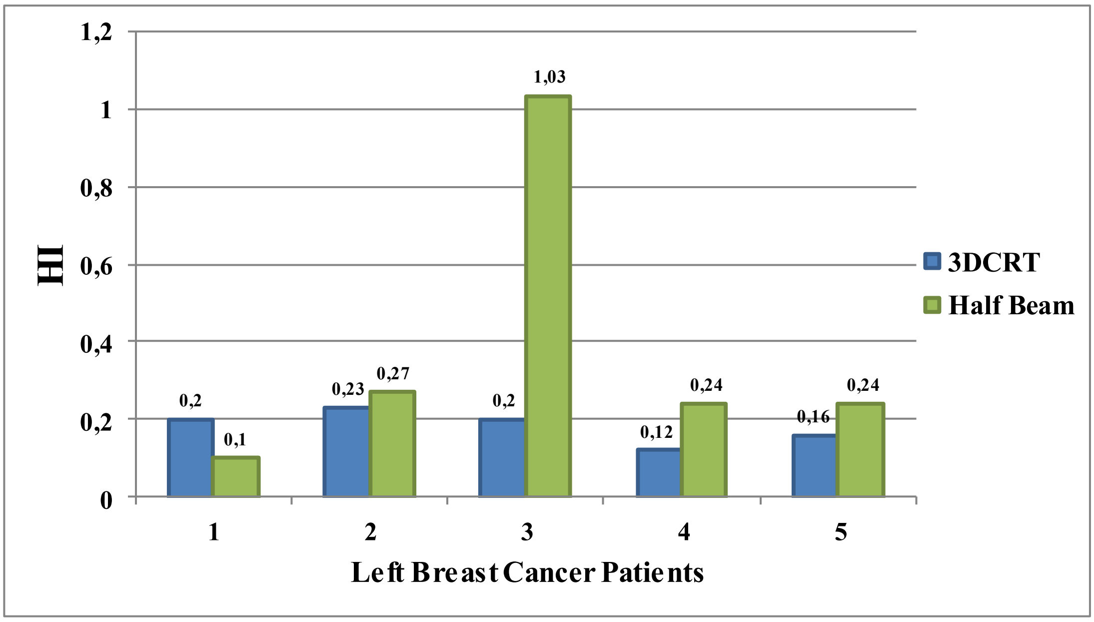

Fig. 5. Comparison of HI Values in 3DCRT and Half Beam Techniques

Based on the comparison in Figure 5, it shows that the Half Beam technique does not meet the values set by the provisions of ICRU Report 83 of 2010 in one of the patients. The HI value obtained in the Half Beam technique is not uniform. This is because the case of patient 3 resulted in an HI value of 1,03. The HI value in patient 3 is due to the value at 98% dose which is very small, so that the dose received by the cancer becomes inhomogeneous. In addition, the HI values of patient 1, patient 2, patient 4, and patient 5 for the Half Beam technique still meet the provisions of ICRU Report 83 of 2010. The HI value of patient 1 is 0,10; patient 2 is 0,27; patient 4 is 0,24; and patient 5 is 0,24. Meanwhile, the HI value obtained by the 3DCRT technique in the five patients has met the requirements according to [12], namely the HI value which is close to 0 with the HI value of patient 1 of 0,20; patient 2 of 0,23; patient 3 of 0,20; patient 4 of 0,12; and patient 5 of 0,16.

Not only HI, the CI value is also needed to determine the suitability of the dose distribution that will be received by the patient [6], to obtain the CI value, a systematic calculation (2) is carried out so that the results of calculating the CI value in the five patients using the 3DCRT and Half Beam techniques are shown in Table 4.

Table 4. CI values for 3DCRT and Half Beam Techniques

Patient	3DCRT			Half Beam		
	$V_{95\%}$ (cc)	V_{PTV} (cc)	CI	$V_{95\%}$ (cc)	V_{PTV} (cc)	CI
1	373,32	308,15	1,21	371,87	315,23	1,18
2	594,53	494,05	1,20	543,36	353,62	1,54
3	518,32	417,70	1,24	421,97	349,82	1,21
4	214,36	160,40	1,34	210,42	199,45	1,06
5	210,02	175,70	1,20	204,73	177,43	1,15

Based on the results shown in Table 4, CI values were obtained for the five patients using the 3DCRT and Half Beam techniques. The 3DCRT technique obtained CIs between 1,20 and 1,34. Meanwhile, the CI value for the Half Beam technique was between 1,06 and 1,54. The ideal CI value is 1, which means that the isodose curve for the prescribed dose exactly covers the PTV [12]. If the CI value obtained is close to 1, the better the level of conformity of the dose distribution with the target shape.

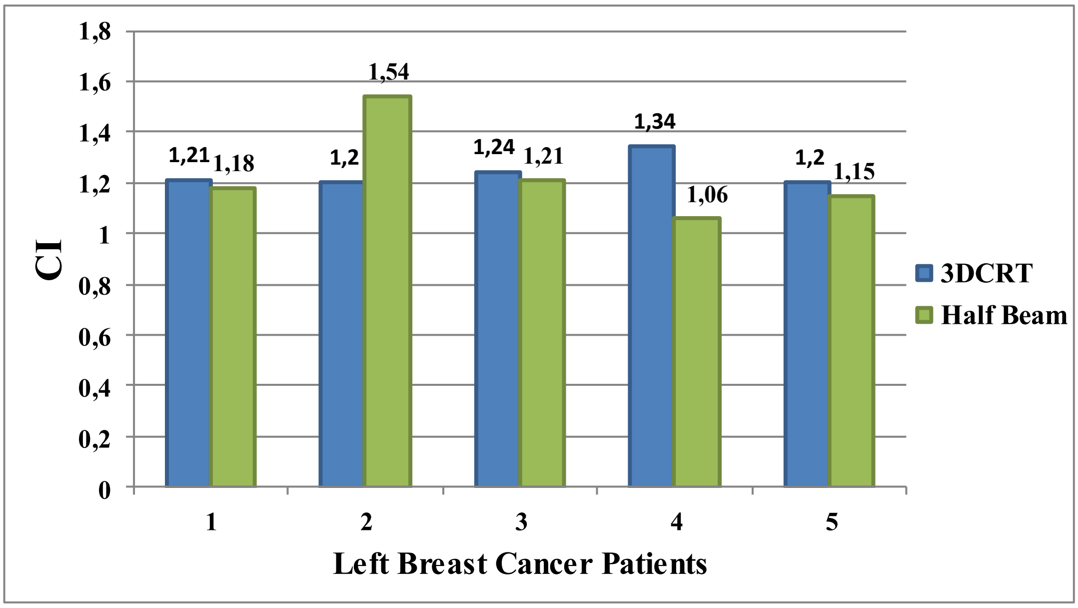

Fig. 6. Comparison of CI Values in 3DCRT and Half Beam Techniques

Based on the comparison in Figure 6 of the five patients using the 3DCRT and Half Beam techniques, the CI value or suitability of the dose distribution with an average value of 1. Thus, both techniques meet the requirements specified by ICRU Report 83 of 2010 and can be applied to patient planning. However, the Half Beam technique has a higher CI value than the 3DCRT technique seen in patient 2 with a Half Beam technique CI value of 1,54 while in the 3DCRT technique the highest CI value obtained is only about 1,34 received by patient 4.

Not much different from the 3DCRT technique, the Half Beam technique has an average CI value for patient 1 of 1,18; patient 2 of 1,54; patient 3 of 1,21; patient 4 of 1,06; and patient 5 of 1,15. From the results obtained in this technique, there is a value that is higher than the average CI value, namely in patient 2. This is due to the 95% PTV volume produced in patient 2 having a higher value than the other patients. Thus, resulting in the CI value obtained is higher than the others. The CI value obtained in the 3DCRT technique for patient 1 was 1,21; patient 2 was 1,20; patient 3 was 1,24; patient 4 was 1,34; and patient 5 was 1,20. The CI values in both techniques show that the 3DCRT technique is closer to the ICRU Report 2010 rules, this is because the average value obtained by the 3DCRT technique does not have too much difference.

IV. Conclusion

Based on the results of research on the comparison of photon dose distribution in breast cancer using 3DCRT and Half Beam techniques, it is concluded that the calculation of dose distribution in the 3DCRT technique produces a more efficient dose value than the Half Beam technique. Comparison of dose distribution can also be seen in the results of HI and CI values. The HI and CI values in the 3DCRT technique are closer to the ideal value, namely the HI value is close to 0 and the CI value is close to 1. From the results obtained, it can be said that the 3DCRT technique for cases of left breast cancer at RSUD A.W. Sjahranie Samarinda has a better value to perform the process of irradiation techniques that will be carried out to patients.

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