# Analysis of Radiation Dose Distribution in Breast Cancer Cases and Organs at Risk (Oar) Using Intensity Modulated Radiation Therapy (Imrt) Technique on A Linear Accelerator (Linac) Equipment With a Photon Beam Energy of 6 MV at the Radiotherapy Sub-Installation of RSUP Prof. Dr. I.G.N.G. Ngoerah


**ABSTRACT**

The aim of the study was to analyze the radiation dose distribution in breast cancer cases using IMRT techniques on a LINAC equipment, specifically examining the Conformity Index (CI), Homogeneity Index (HI), and radiation dose distribution to the OAR, including lungs and heart on a 6 MV photon beam energy LINAC equipment at the Radiotherapy Sub-Installation of Prof. Dr. I.G.N.G Ngoerah Hospital. Analysis of the Conformity Index (CI), Homogeneity Index (HI) and radiation dose distribution to the OAR, namely the lungs and heart in cases of right and left breast cancer using statistical data on the Dose Volume Histogram (DHV) graphic obtained from patient calculations using the Treatment Planning System (TPS) Monaco. The CI value for the right and left breast cancer cases is 0.9819 and 0.9942 respectively with a nonparametric statistical test result of 0.141 that greater than 0.05 which means it is not significant. Meanwhile, the HI values for the right and left breast cancer cases are 0.1211 and 0.1410 respectively with the multivariate statistical test result of 0.159 that greater than 0.05 which means it is not significant. For the dose distribution values in the lungs close and far from the cancer, the average values of 32.24% and 440.03 cGy for right breast cancer and 33.04% and 500.55 cGy for left breast cancer were obtained, respectively, with a multivariate statistical test value for both of them of 0.115 that greater than 0.05 in the lungs close to the cancer and 0.124≥0.05 in the lungs far from the cancer, which means insignificant. As for the heart, a value of 3.13% was obtained for right breast cancer and 8.02% for left breast cancer with a nonparametric statistical test result of 0.000 that less than 0.05 which means significant. This can be caused by the position of the heart in cases of left breast cancer closer to the target or cancer than cases of left breast cancer.



**Keywords:** Breast Cancer, Lung, Heart, IMRT, CI, HI




## I Introduction

The incidence of cancer worldwide continues to rise to 18.1 million with new cases and 9.6 million deaths [1]. There are 2.1 million cases of breast cancer in women annually [2]. In 2017, the Minister of Health of the Republic of Indonesia conducted an early detection examination for cervical and breast cancer, which resulted in 3,079 people suspected of having breast cancer [3]. One of the methods for treating breast cancer is through radiation therapy, which utilizes ionizing radiation to kill cancer cells as much as possible while minimizing damage to normal tissue. The Linear Accelerator (LINAC) is one of the teletherapy machines designed to accelerate the linear movement of electrons, producing electron and photon beams [4]. The use of LINAC in cancer treatment has the potential to provide radiation doses that do not match the planned radiation doses, thus requiring radiation dose verification to ensure that the radiation dose given to patients is accurate and consistent with the radiation dose in the Treatment Planning System (TPS) [5].

The purpose of the TPS is to adjust the dose to the target volume and reduce the dose to the surrounding Organs at Risk (OAR). In determining the radiation dose distribution for breast cancer, the TPS and Multileaf Collimator (MLC) are used, where the TPS is used for calculating the radiation dose distribution for breast cancer and the MLC itself serves as a shaping and field size for the tumor and protects OAR such as the lungs and heart [5]. The radiation intensity changes on the LINAC machine are modified by creating several segments on each radiation field formed by the MLC based on the shape of the target tumor and the dose limits of the organs at risk around the tumor. In IMRT technique, the MLC collimates and attenuates the radiation that comes out of the LINAC machine according to the expected dose distribution.

### I.I Breast Cancer

Cancer is one of the disease that leading causes of death worldwide. In 2012, around 8.2 million deaths occurred due to cancer, one of which is breast cancer. Breast cancer is a disease that can cause pain and even death in patients [6]. That is why breast cancer is one of the most feared cancers among women among many types of cancer. In 2010, data from the Ministry of Health of Indonesia indicated that breast cancer was the second highest cause of mortality for women in Indonesia, following cervical cancer [7]. Until now, the root cause of breast cancer is not known yet, but some experts suggest that the cause can only be marked in women who have risk factors such as having a history of tumors or cancer in their family members, starting menstruation at a young age, menopause over the age of 50, giving birth to the first child over the age of 35, and an unhealthy diet by consuming excessive fats [6].

### I.2 Radiotherapy

Radioterapi is a medical procedure that uses ionizing radiation to kill cancer cells as much as possible while minimizing damage to normal cells [8]. The dose given to the target organ in radiotherapy must be precise by trying to keep the dose to other parts of the body as low as possible. Excessive doses will endanger the patient, while low doses will also affect the patient's healing. The use of radiation in radiotherapy can treat almost all types of solid tumors in organs such as brain, breast, cervix, throat, lung, pancreas, prostate, skin, and so on. There are two methods of radiotherapy, namely brachytherapy and external radiation or teletherapy. Brachytherapy (close-range radiation) is a radiation therapy method that places the radiation source near the target area. Meanwhile, the use of a radiation sources in a certain distance from the body, called teleteraphy. External therapy includes radiation therapy that uses Co-60 therapy machines, Linear Accelerators (LINAC), Cs-137 therapy machines, and so on [9].

### I.3 Linear Accelerator (LINAC) Machine

The Linear Accelerator, commonly referred to as LINAC, employs high-frequency electromagnetic waves to propel charged particles such as high-energy electrons in a linear tube. This device can be utilized to treat tumors located near the surface of the body with the high-energy electron beam, or by colliding the electrons with a target to produce X-rays that can be utilized to treat tumors located deeper within the body [8]. The ionization process resulting from the interaction of ionizing radiation (photon and electron beams) with matter (cancer) will cause the deoxyribose nucleic acid (DNA) chain of cancer to be disrupted, thereby killing the cancer tissue [11]. The amount of monitor units (MU) needed as input is influenced by various factors such as the desired dose size, the depth of the cancer, the reference dose rate or calibration of the monitor, the collimator setting size, the size of the cancer field, and other variables [12]. The current LINAC machine is equipped with various accessories called the Multilief Colimator (MLC), which is a sheet of lead that serves as a replacement for individual blocks to regulate the intensity of the radiation target. The shape of the MLC is adapted to the shape of the planned tumor or cancer in the Treatment Planning System (TPS), so that the Organ At Risk (OAR) could be protected [13].

### 1.4. Intensity Modulated Radiation Therapy (IMRT)

IMRT is a modern technique in radiotherapy that uses multiple radiation fields with non-uniform intensity in each direction to achieve optimum dose distribution. The radiation intensity changes in the LINAC machine are modified by creating several segments in each radiation field formed by the MLC based on the shape of the tumor target and the dose limit of the organs at risk around the tumor. In IMRT technique, MLC acts to collimate and attenuate the radiation that comes out of the LINAC machine according to the expected dose distribution. To implement the IMRT technique, a TPS computer is needed that can perform calculations for multiple radiation fields with non-uniform intensity from each direction of irradiation in an inverse manner, and a radiation machine that can provide radiation with non-uniform intensity according to what is planned by the TPS computer [14]. Additionally, the determination of the target volume in TPS is based on a simulation process using a CT-Simulator machine to obtain images of the patient. The Treatment Planning System (TPS) includes several elements within the target volume, such as the Gross Tumor Volume (GTV), Clinical Target Volume (CTV), Planning Target Volume (PTV), and Organs At Risk (OAR) [15].

### 1.5 Conformity Index (CI)

Conformity Index (CI) is the ratio of the volume of PTV coverage to the total volume of PTV. The adequacy of the dose distribution with the tumor target is determined by the CI value. In ICRU report 83, CI is defined as the level of conformity of the prescription dose covering the tumor target and is formulated with an ideal CI value of 1, which means that the isodose curve for the prescription dose precisely matches the PTV [16]. The equation for calculating CI is as follows:

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

Information:

CI = Conformity Index

$V_{95\%}$ = Total volume that received the 95% dose ($cm^3$)

$V_{PTV}$ = Total volume PTV on radiation target ($cm^3$)

### 1.6 Homogenity Index (HI)

The Homogeneity Index (HI) is the ratio between the minimum dose volume to the maximum dose volume that has been determined. Homogeneity of the dose within the target volume is determined by the HI value [16]. In the ICRU report 83, HI is defined as the uniformity of the dose distribution within the target volume. The ideal value for HI is 0, which means that the entire dose in the PTV is homogeneous. The acceptable range for HI according to the ICRU criteria is 0-0.3. HI is influenced by the minimum dose, maximum dose, and average dose in the target. The equation for calculating HI is as follows [17]:

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}} \quad (2)$$

Information:

HI = Homogenity Index

$D_{2\%}$ = The amount of dose which cover 2% PTV volume (cGy)

$D_{98\%}$ = The amount of dose which cover 98% PTV volume (cGy)

$D_{50\%}$ = The amount of dose which cover 50% PTV volume (cGy)

### 1.7 Dose Volume Histogram (DVH)

Dose Volume Histogram (DVH) is a chart that used in radiation therapy planning that shows the relationship between radiation dose and tissue volume. By examining the DVH, important information about the distribution of radiation dose received by the patient's tumor target and Organs At Risk (OAR) can be obtained from a two-dimensional (2D) graph and statistical data [18].

### I.8 Research Method

This study was conducted on 30 patients with right breast cancer and 30 patients with left breast cancer at the Radiotherapy Sub-Installation of Prof. Dr. I.G.N.G Ngoerah Hospital. The stages of this study are as follows: firstly, patients will be scheduled for simulation, then during the simulation process using a CT-Simulator machine, imaging results will be obtained and sent to the TPS for imaging by radiation oncology specialists in the form of targets or cancer as well as OAR which include the far lung from cancer, the near lung from cancer, and the heart. Next, the medical physicist will perform calculations on the TPS Monaco computer using the IMRT technique, with several parameters set including a total dose of 5000 cGy, dose per fraction of 200 cGy, and using 7 beam directions.

From each calculation using TPS Monaco, the distribution of dose values for each patient in the form of statistical data from the 2D DVH graph will be obtained, such as the VPTV value, V95%, D2%, D50%, D98%, and the dose distribution received by OAR such as the percentage value and the dmean value. From the obtained dose distribution data, an analysis will be carried out using equations 1 and 2 to obtain the calculation of the CI and HI values, while for the dose distribution in OAR, it will be compared to the established limits based on Radiation Oncology A Question-Based Review for each OAR. In addition, statistical tests will be performed using Statistical software suite (SPSS) version 25 to determine whether there are significant differences in the calculations for right and left breast cancer cases.

### 1.9 Data Analysis

The results of TPS planning using IMRT technique with CI, HI, and OAR parameters were then compared with the predetermined limits of each parameter. To determine whether the obtained parameter values exceed the limits or not, statistical tests were conducted, namely paired-sample t-test and nonparametric Wilcoxon test using SPSS software version 25. The testing was conducted with a 95% confidence level or a significance level of 0.05, with the following hypotheses:

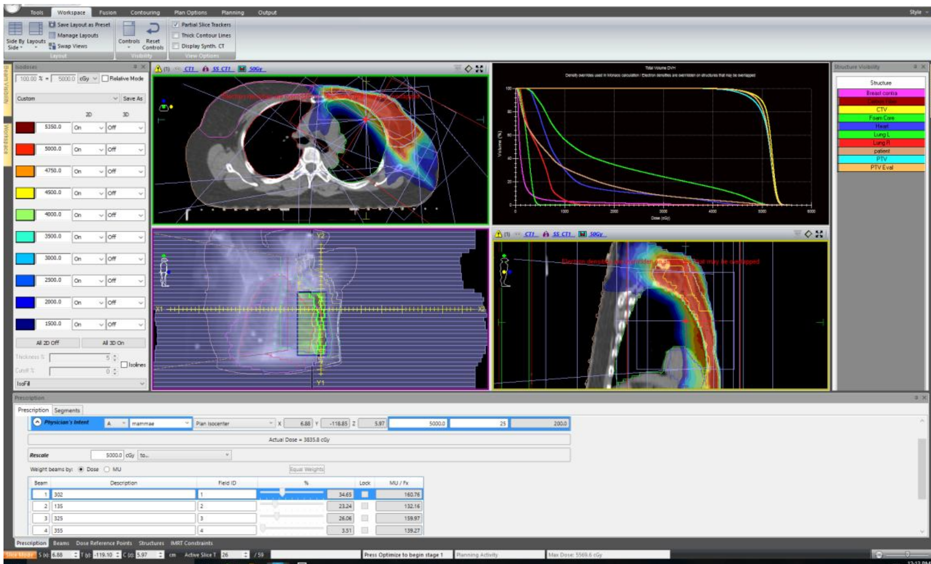
H0: There is no difference between the calculated values of CI, HI, and maximum dose received by OAR parameters and the predetermined values of CI, HI, and maximum dose received by OAR parameters.

H1: There is a difference between the calculated values of CI, HI, and maximum dose received by OAR parameters and the predetermined values of CI, HI, and maximum dose received by OAR parameters.

From the results of the statistical tests, the obtained significance level will be compared. If the significance level is greater than 0.05, H0 is accepted and H1 is rejected (not significant), otherwise, if the significance level is less than 0.05, H0 is rejected and H1 is accepted (significant). From these results, it can be determined whether there are any differences in the dose distribution in PTV and OAR at the Radiotherapy Sub-Installation of Prof. Dr. I.G.N.G. Ngoerah Hospital or not.

## II. Result and Discussion

The results of this study were obtained from calculations on TPS Monaco in the form of radiation dose distribution values in statistical data from the DVH graph. The DVH graph is a histogram that connects the radiation dose distribution values with the volume of the target tumor or OAR in radiation therapy planning. Here is one of the display results from the calculation of dose distribution in the cases of right and left breast cancer using TPS Monaco with serial number 5.11.03:



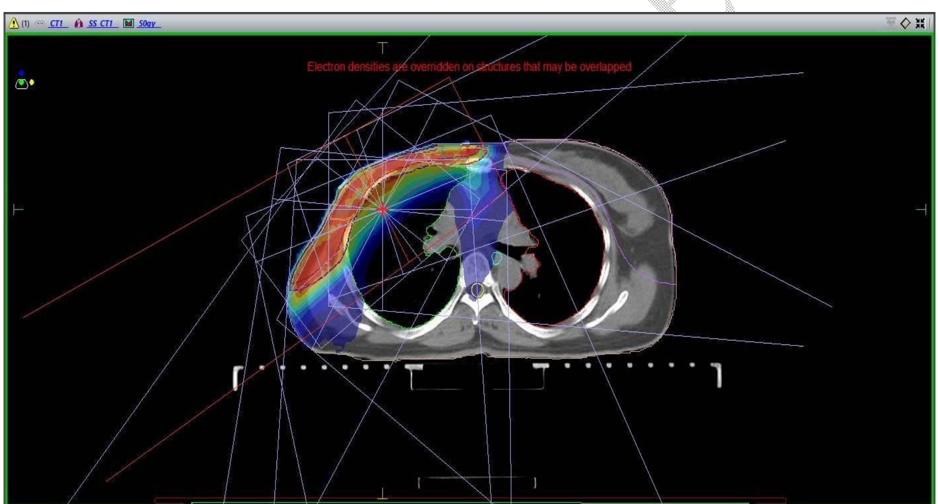

Electron densities are overridden on structures that may be overlapped

Figure :

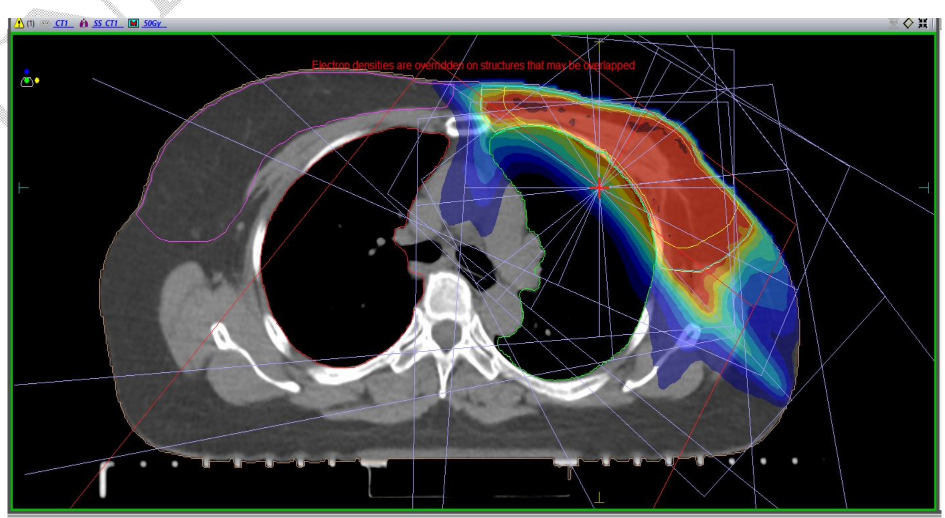

Electron densities are overridden on structures that may be overlapped

**Figure 2** Radiation Dose Distribution of Left Breast Cancer

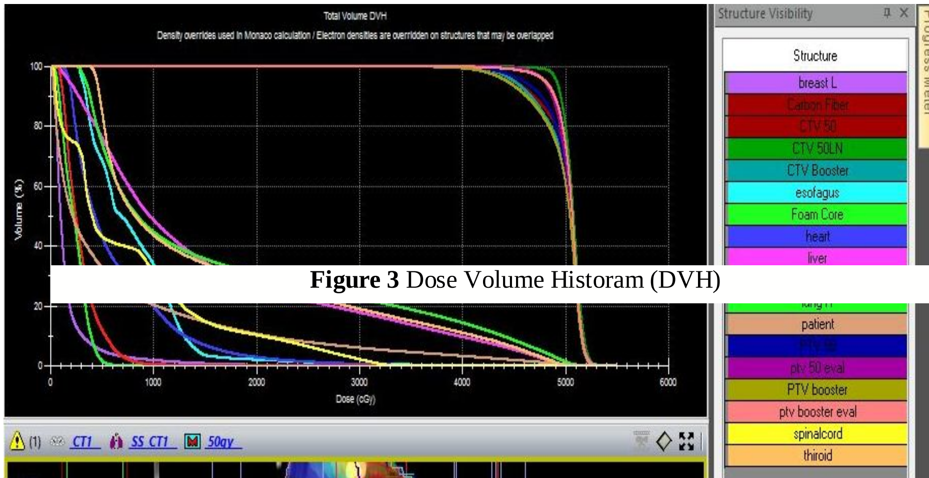



**Figure 3** Dose Volume Historam (DVH)

ased on the research results, data on dose distribution were obtained from the statistical DVH graph in cases of right and left breast cancer in the form of dose distribution data in the VPTV, V95%, D2%, D50%, D98% areas, as well as OARs such as lungs near the cancer, lungs far from the cancer, and heart. The data was then calculated to obtain the CI and HI values in the PTV area, while for OARs, the radiation dose distribution obtained was compared with the limits set based on Radiation Oncology A Question-Based Review. The results of the CI, HI, and OAR calculations for right and left breast cancer cases can be illustrated in the comparison graph below:

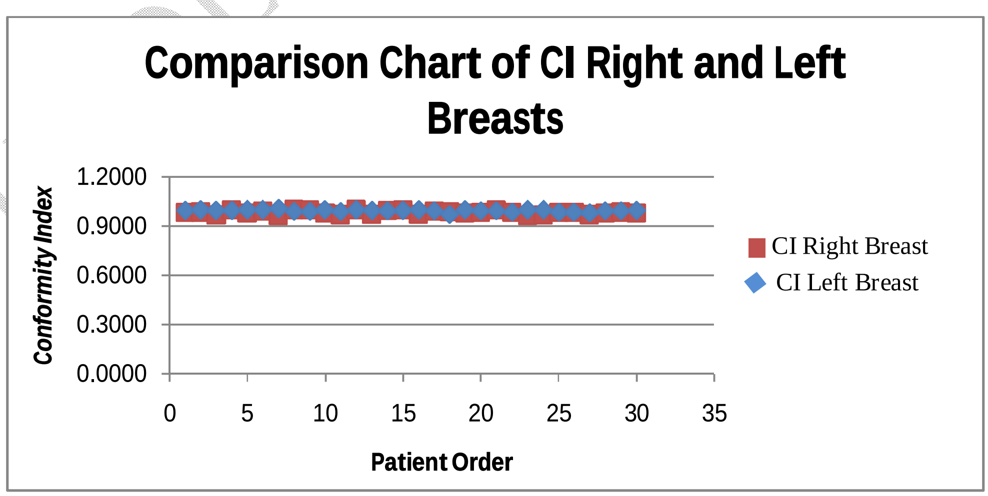



**Figure 5** Comparison Chart of CI Right and Left Breasts

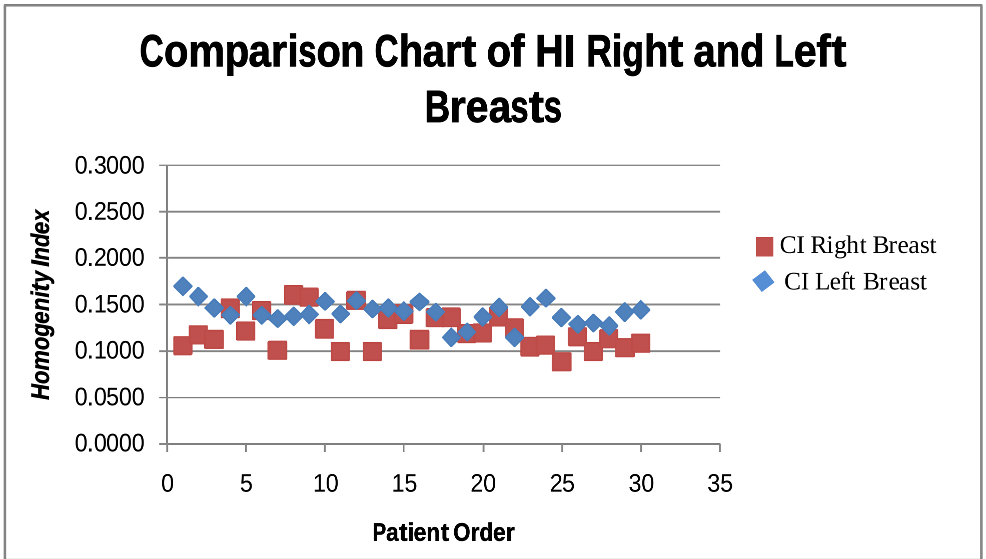



**Figure 6** Comparison Chart of HI Right and Left Breasts

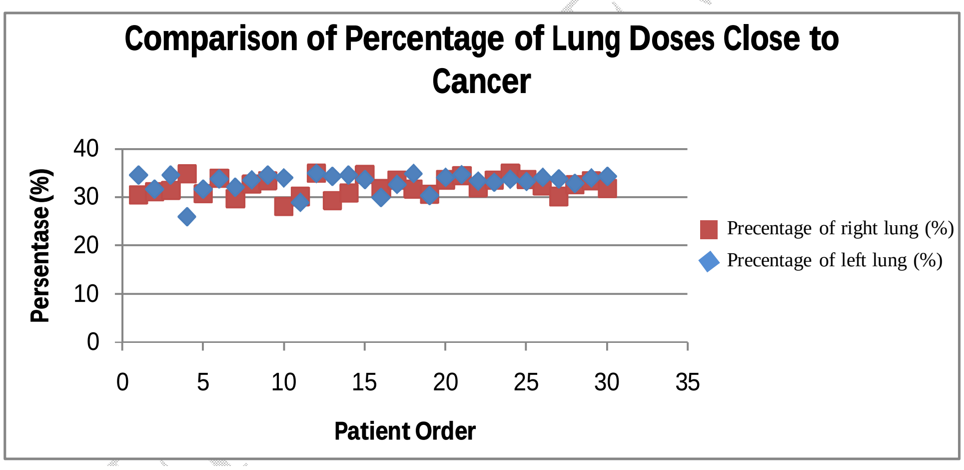



**Figure 7** Comparison of Percentage of Lung Doses Close to Cancer

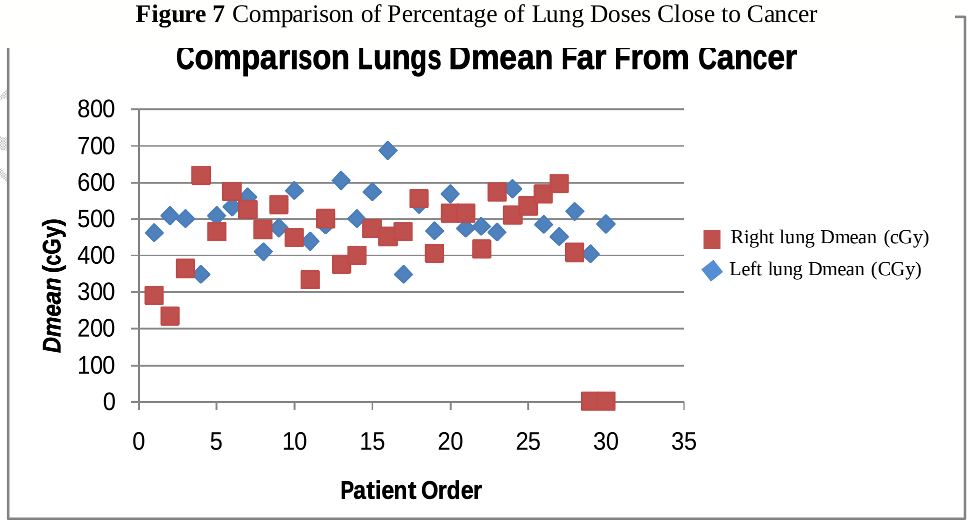



**Figure 8** Comparison Lungs Dmean Far From Cancer

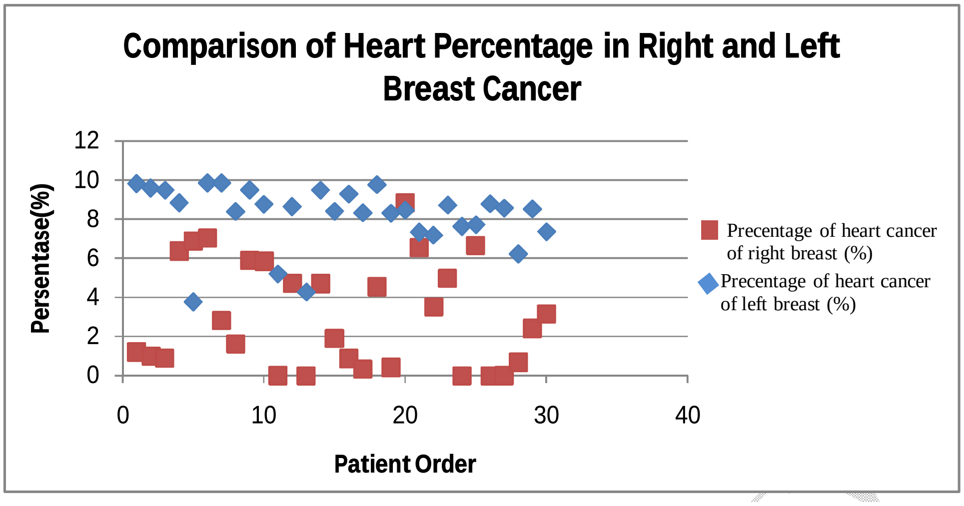



**Figure 9** Comparison of Heart Percentage in Right and Left Breast Cancer

Based on the calculation results of CI, HI, and OAR values on the right and left breast cancer cases, statistical tests were also conducted on these results using Statistical software suite (SPSS) software version 25 with a significance level of ≤0.05. This aims to determine whether there are several significant differences in the calculation values between the right and left breast cancer cases. The average values of the calculation results can be seen in the table below:



| | Average Right Breast Cancer Dose Distribution | Average Left Breast Cancer Dose Distribution | *Sig. (2-tailed)* | *Asimp.Sig. (2-tailed)* |
|---|---|---|---|---|
| *Conformity Index* (CI) | 0,9819 | 0,9942 | | 0,141 |
| *Homogenity Index* (HI) | 0,1211 | 0,1410 | 0,159 | |
| Precentage of lungs which near the cancer | 32,24 | 33,04 | 0,115 | |
| *Dmean* of breast which far from cancer | 440,03 | 500,60 | 0,124 | |
| Heart precentage | 3,13 | 8,20 | | 0,000 |

Table 1 shows that the average Conformity Index (CI) value for right and left breast cancer cases was 0.9819 and 0.9942 respectively, with a nonparametric statistical test result of 0.141≥0.05, indicating an insignificant value. Similarly, the average Homogeneity Index (HI) value for right and left breast cancer cases was 0.1211 and 0.1410 respectively, with a multivariate statistical test result of 0.159≥0.05, also indicating an insignificant value. These values are in line with the ICRU 83 standards set in 2010, where CI is set at 1 and HI is set between 0 to 0.3. These results suggest that the overall dose distribution for both right and left breast cancer patients is appropriate and homogeneous.

Additionally, regarding the calculation of radiation dose distribution values for each Organ At Risk (OAR) for breast cancer cases, the average percentage of radiation dose received by the lung near the cancer was 32.24% for right breast cancer and 33.04% for left breast cancer, with a multivariate statistical test result of $0.115 \geq 0.05$, indicating an insignificant value. Similarly, the average radiation dose received by the lung far from the cancer was 440.03 cGy for right breast cancer and 500.60 for left breast cancer, with a multivariate statistical test result of $0.124 \geq 0.05$, indicating an insignificant value. However, the average radiation dose distribution on the heart was 3.13 for right breast cancer cases and 8.20 for left breast cancer cases, with a nonparametric statistical test result of $0.00 \leq 0.05$, indicating a significant value. This difference in radiation dose distribution values may be due to the heart's location, which is more inclined towards the left side of the human body. Thus, when the cancer is located in the left breast area, it is closer to the heart, resulting in a higher radiation dose distribution value compared to when the cancer is in the right breast.

## III. Conclusion

Based on the calculation results, it can be concluded that the values of radiation dose distribution in the case of right and left breast cancer and their OARs are still appropriate and consistent when compared to the values determined based on ICRU 83 in 2010, with the obtained statistical test result being not significant. As for the radiation dose distribution values received by each OAR, the statistical test values for the percentage of lungs near the cancer and Dmean of lungs far from the cancer are not significant. However, for the percentage of the heart in cases of right and left breast cancer, the obtained statistical test value is significant. The difference in radiation dose distribution values may be due to the location or position of the heart being closer when the cancer is in the left breast compared to the position of the heart when the cancer is in the right breast.



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