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Analysis of Wedge Angle Variations in the Treatment Planning System Based on Dose Volume Histogram on Ca Mammae Sinistra

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ABSTRACT

Breast cancer ranks first in terms of the highest number of cancers in Indonesia. According to IARC, radiotherapy is one of the most important modalities in the treatment of breast cancer. Radiotherapy is a type of treatment that uses ionizing radiation to kill cancer cells without damaging surrounding healthy tissue. To obtain an even or homogeneous dose distribution on an uneven skin surface, a wedge is used so that the radiation given to the tumor area is optimal and the surrounding healthy tissue gets a minimum dose. This research was carried out by evaluating the Planning Target Volume (PTV) value based on ICRU-83 and dose distribution to Organs at Risk (OAR) based on QUANTEC standards at four different wedge angles, namely 15°, 30°, 45° and 60°. Treatment Planning System (TPS) was carried out using the 3D-CRT technique with tangential irradiation with a dose of 50 Gy in 25 fractions on 5 left-sided breast cancer patients. Each patient was planned 4 times for each different wedge angle so that 16 image data were used for 1 patient. The research results showed that the average Homogeneity Index (HI) values for the 15°, 30°, 45° and 60° wedges were 0.286, 0.346, 0.436 and 0.578, respectively. In the left and right lung dose distribution, the results obtained for the 15°, 30°, 45°, and 60° wedge were respectively 2231.4 cGy and 116.2 cGy, 2257.8 cGy and 114.6 cGy, 2141 cGy and 100 cGy, and 2059.4 cGy and 88.8 cGy. For the average dose distribution to the heart, the values obtained at the 15°, 30°, 45°, and 60° wedges were 2005.6 cGy, 2040.4 cGy, 1930.6 cGy, and 1844.4 cGy, respectively. where the average dose received by OAR is still below the limit allowed by QUANTEC. Using a wedge angle of 15° provides a homogeneous dose distribution for the PTV and a wedge angle of 60° provides the lowest dose distribution for the OAR.

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I. Introduction

Breast cancer (carcinoma mammae/ca mammae) is a malignancy that originates from breast tissue from both the duct epithelium and the lobules. Ca mammae occurs due to the condition of cells that have lost their normal control and mechanisms, so they experience abnormal, fast and uncontrolled growth [1].

Mammary glands (breasts) are owned by both sexes, but these glands become very important in women during puberty and are very sensitive to the hormone estrogen. Meanwhile, in men it usually does not develop (rudimentary). During pregnancy, the mammary glands reach their peak development and function for milk production (lactation) after delivery [2]. Uncommon signs and symptoms of breast cancer include breast pain or feeling heavy, rapid breast changes such as swelling, thickening, redness of the skin and abnormalities in the nipple/nipple pulling inward [3].

Radiotherapy is a type of treatment that uses ionizing radiation to kill cancer cells without damaging surrounding healthy tissue. The basic principle of radiotherapy is to deliver a lethal dose of radiation to a predetermined area of the tumor (target volume) and a minimal dose to the surrounding normal tissue. One of the therapeutic tools used is the Linear Accelerator (Linac) [4][5].

The Linac plane is the most widely used external radiation therapy device for cancer patients. When using the Linac for radiation therapy, electron beam energies (4, 6, 9, 12, 15, and 18 MeV) and photon beam energies (6 and 10 MV) are used. The use of high ionizing radiation can have a damaging effect on normal tissue or organs at risk (OAR). The heart and lungs are OARs for breast cancer, and careful and appropriate radiation therapy planning is needed to prevent this. This planning can be done on the Treatment Planning System (TPS) computer. Planning is carried out to determine the dose distribution that the patient will receive before irradiating the patient [6].

The uneven skin surface in the tumor area results in an air gap, so to influence the effect of the air gap on the uneven skin surface, a wedge is used as compensation for the radiation. The use of a wedge is the most effective way to obtain an even or homogeneous dose distribution over an uneven skin surface, so that the radiation given to the tumor area is truly optimal and the surrounding healthy tissue receives a minimum dose. The wedge functions as radiation protection for patients because it can minimize the radiation dose to the tissue around the tumor [7].

Changing the wedge angle did not increase the average PTV dose percentage or eliminate hotspot/coldspot areas [8]. The wedge filter at an angle of 15° provides a more homogeneous and optimal dose distribution to the PTV [9]. There is a significant effect of wedge variations on the Homogeneity Index (HI) value, but there is no significant effect of wedge variations on the dose received by the right lung OAR. In PTV, a homogeneous dose distribution is obtained when planning using a wedge angle of 15° because the value obtained is lower than the HI value for other wedge variations [10].

Therefore, the researchers chose the research title "Analysis of Wedge Angle Variations in the Treatment Planning System Based on the Dose Volume Histogram (DVH) of Ca Mammae Sinistra in the Radiotherapy Installation of A. W. Sjahranie Hospital Samarinda". This research was carried out by analyzing the Dose Volume Historgam (DVH) at the Planning Target Volume (PTV) dose evaluated at the location of the maximum dose (D_{max}) based on the ICRU-62 standard, then calculating the Homogeneity Index (HI) value, while the OAR of the heart and lungs was evaluated average dose (D_{mean}) based on QUANTEC standards with different wedge angle variations, namely 15°, 30°, 45°, and 60°.

II. Method

This research was carried out by implementing a Treatment Planning System (TPS), where researchers will carry out radiation planning in the Radiotherapy Installation in the TPS room at Abdoel Wahab Sjahranie Hospital, Samarinda. TPS in left-sided breast cancer uses the 3D-CRT technique with tangential field irradiation. TPS aims to determine radiation energy, field area, number of radiation fields, dose distribution calculations, radiation direction and MLC settings that will be treated using radiation. The TPS determined in this research uses different wedge angle variations, namely 15°, 30°, 45° and 60°. The Treatment Planning System (TPS) steps that will be carried out by researchers are:

1. Patient Data, obtained from patient data at RSUD A.W. Sjahranie Samarinda with a diagnosis of left-sided breast cancer, totaling 5 patient data;
2. Determine the target volume, after obtaining imaging data for breast cancer patients from the CT-Simulator, then a dose of 2 Gy in 25 fractions is given (the dose is determined by the Radiation Oncologist);
3. Adjust the gantry and collimator angles, where the gantry angles used in this research are 310° and 120^°, while the collimator angles are 90° and 270°;
4. Set the wedge angle with variations in the wedge angle used, namely 15°, 30°, 45°, and 60°; And

5. Calculation, final calculation to display DVH.

There are 4 plans used in this research, namely for planning on a 15° wedge using gantry angles of 310° and 120°. In the first planning, when the gantry angles were 310° and 120°, collimator angles of 90° and 270° were used. For the second planning, when the gantry angles are 310° and 120°, collimator angles of 270° and 90° are used. Then, for the third planning when the gantry angles are 310° and 120°, collimator angles of 90° and 90° are used. Then, for the fourth planning when the gantry angles are 310° and 120°, collimator angles of 270° and 270° are used. Then, an analysis of the values received by the target volume and OAR (heart and lungs) is carried out. Perform the same steps on the 30°, 45°, and 60° wedges.

Homogeneity Index (HI) is a quantitative parameter used to analyze the uniformity of dose distribution in the target volume. The ideal HI value based on ICRU Report 62 is 0, which means that all doses in the PTV are homogeneous. The HI value is caused by the minimum dose, average dose and maximum dose at the target [11]. The HI formulation is as follows [12]:

:

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}} \quad (1)$$

$D_{2\%}$ = Dose that covers 2% of the cancer volume
$D_{98\%}$ = Dose that covers 98% of the cancer volume
$D_{50\%}$ = Dose that covers 50% of the cancer volume

III. Results and Discussion

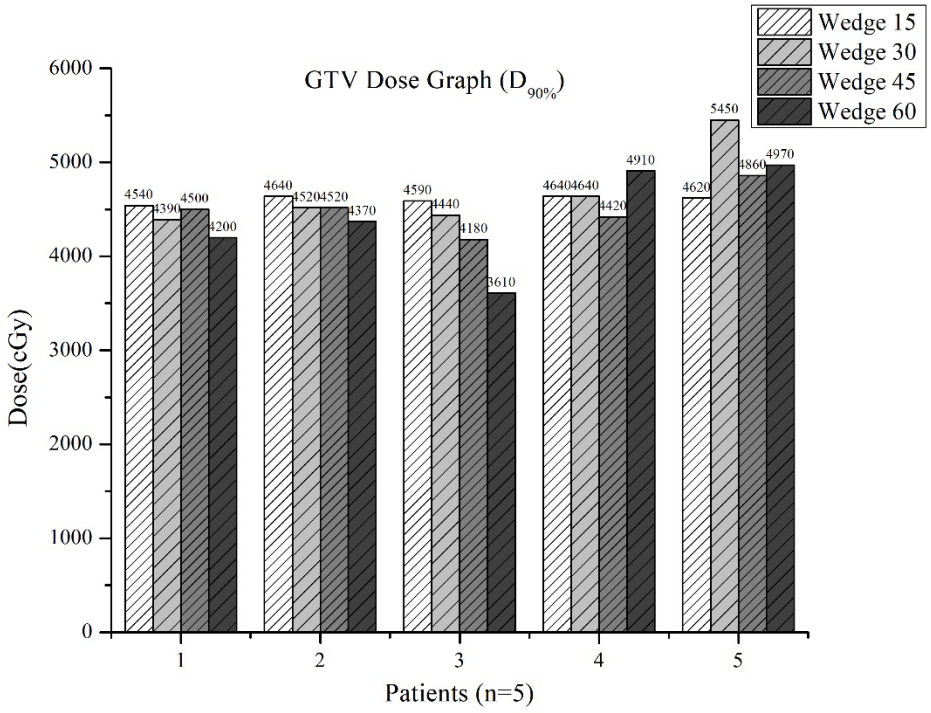

Fig. 1. GTV Dose Graph ($\mathbf{D_{90\%}}$)

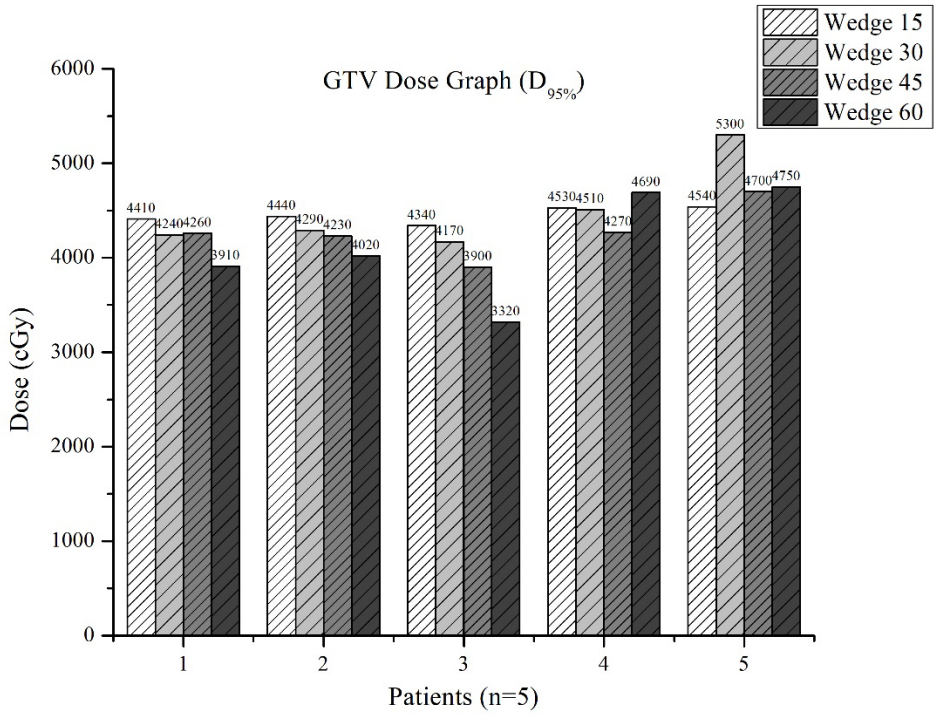

Fig. 2. GTV Dose Graph **($D_{95\%}$)**

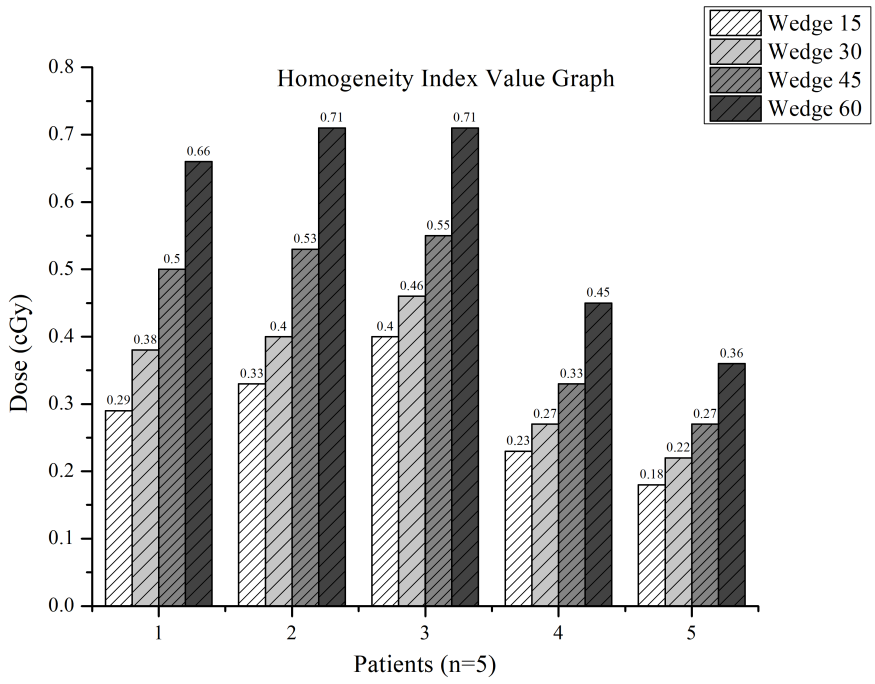

Fig. 3. Homogeneity Index Value Graph

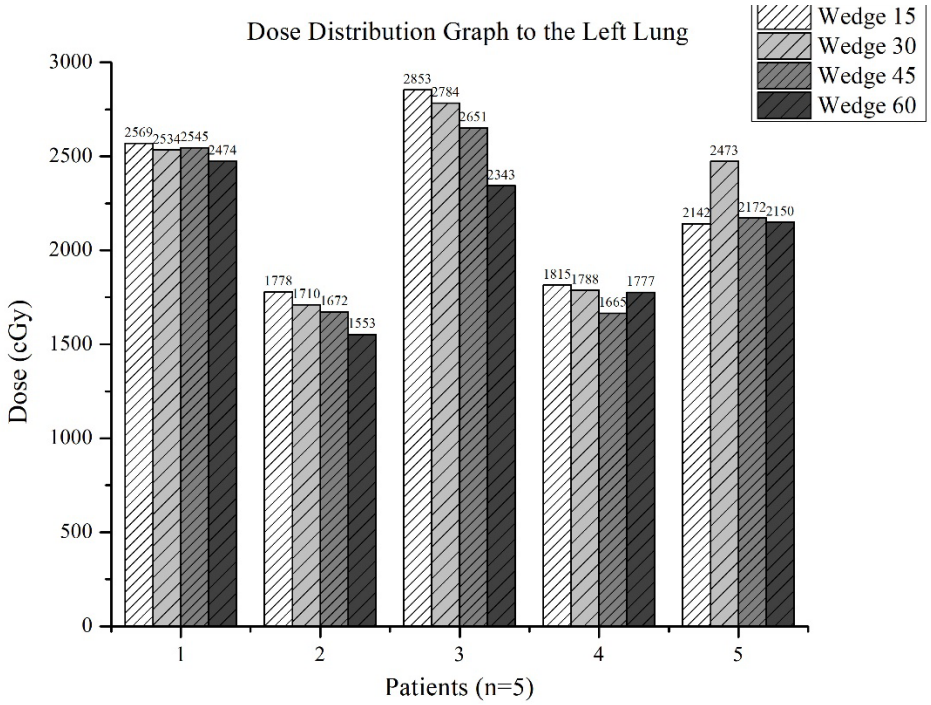

Fig. 4. Dose Distribution Graph to the Left Lung

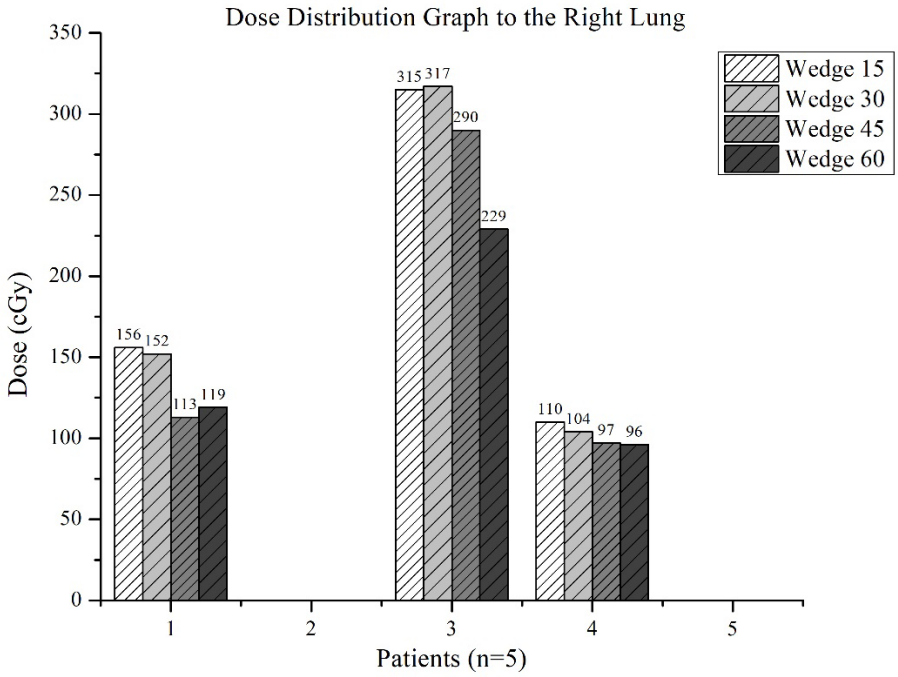

Fig. 5. Dose Distribution Graph to the Right Lung

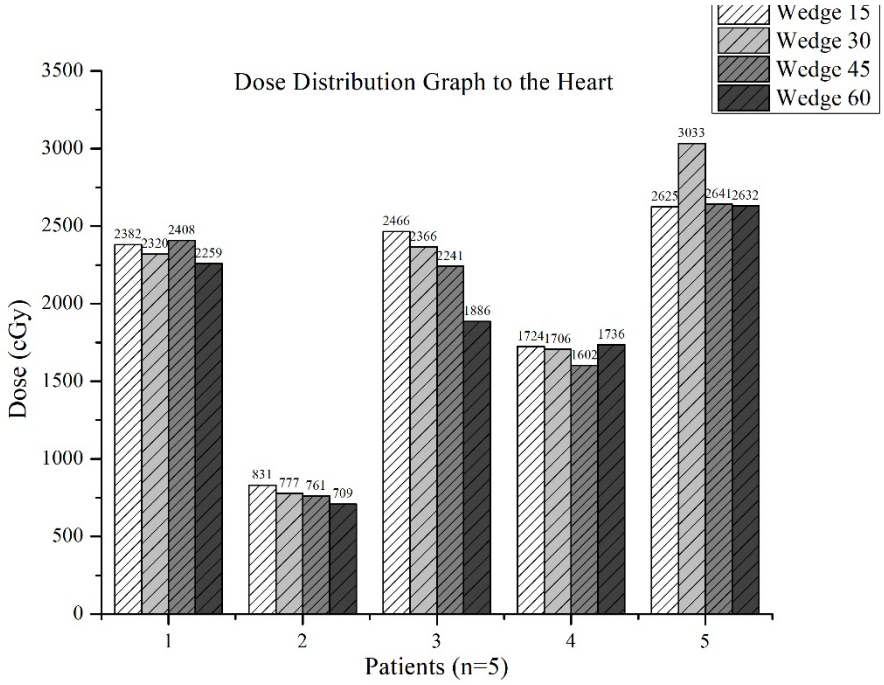

Fig. 6. Dose Distribution Graph to the Heart

Fig. 1 displays a dose graph that covers 90% of the target, namely 4500 cGy which is used as the minimum dose that must be received by the tumor target. The calculation of the GTV $D_{90\%}$ radiation dose can be seen in the DVH table taken at the 90% point of the target volume at each wedge angle variation of 15°, 30°, 45° and 60°. In the TPS results, which are viewed from the DVH results at a dose of 90%, the average target volume radiation dose at the 15° wedge is 4606 cGy, at the 30° wedge is 4688 cGy, at the 45° wedge is 4496 cGy, and at the 60° wedge of 4430 cGy. Based on the results obtained at the 15° and 30° wedge the minimum radiation dose received by the target was met, whereas at the 45° and 60° wedge the radiation dose received was still below the minimum radiation dose planned so that the target could be covered, where the minimum dose planned so that the target can be covered is 90% (4500 cGy).

Fig. 2 shows a dose graph that covers 95% of the target, namely 4750 cGy which is used as the maximum dose that must be received by the tumor target. The calculation of the GTV $D_{95\%}$ radiation dose can also be seen in the DVH table taken at the 95% point of the target volume at each wedge angle variation of 15°, 30°, 45° and 60°. Based on the TPS results in terms of DVH results at a dose of 95%, it was found that the average target volume radiation dose at the 15° wedge was 4452 cGy, at the 30° wedge was 4502 cGy, at the 45° wedge was 4272 cGy, and at the 60° wedge of 4138 cGy. Based on the results obtained at wedges of 15°, 30°, 45°, and 60°, the maximum radiation dose is still below the radiation dose planned so that the target can be covered, where the maximum dose planned so that the target can be covered is 95% (4750 cGy).

The majority of the dose for 95% of the target volume is not met, this is influenced by the use of varied wedges and the number of fields used is only 2, which causes hot spots, the tumor is not completely covered, and increases the dose which spreads to other areas such as the lungs and the heart thereby increasing the dose received by OAR.

Based on figure 1, the maximum radiation dose that the target must receive is 95% and figure 2 shows the minimum radiation dose that the target must receive is 90%. There are differences in DVH results between each patient caused by differences in the target volume for each patient. In the DVH results graph it can be seen that the radiation dose at $D_{90\%}$ is greater than the radiation dose at $D_{95\%}$, which gradually decreases followed by an increase in target depth, because the greater the target depth, the more energy the electrons or photons will have. the more it is used to interact with the atoms that make up the target or organ.

To determine the Homogeneity Index (HI) value in order to describe the dose distribution for PTV based on the ICRU-62 standard, a calculation is used using the formula in equation (1). Figure 3 shows

the HI value graph. It is known that the average HI value at a wedge angle of 15° is 0.286, at a wedge angle of 30° is 0.346, at a wedge angle of 45° is 0.436, and at a wedge angle of 60° is 0.578. Based on the results obtained, it can be concluded that there is a significant difference in the dose received by PTV when using variations in wedge angles of 15°, 30°, 45°, and 60°. From the average HI values obtained at varying wedge angles of 15°, 30°, 45°, and 60°, all values are close to perfect (= 0).

For optimal and homogeneous wedge variations for PTV, the researchers took a wedge angle of 15° because the average HI value obtained was lower than the average HI value at wedge angles of 30°, 45°, and 60°. This is in accordance with the research results of [8][9] which stated that homogeneous dose distribution in PTV can provide optimal radiation therapy for cancer treatment, one way to evaluate this is by calculating the HI value and it was found that a wedge angle of 15° provides a homogeneous dose distribution in PTV.

OAR analysis was carried out by comparing the dose distribution received from radiotherapy treatment at TPS with the tolerated dose recommended by QUANTEC. For the radiation dose received by the OAR to the lungs (right and left), researchers took the QUANTEC standard reference, namely less than 2700 cGy (≤ 27 Gy).

Figures 4 and 5 display dose distribution graphs in the left and right lungs. In the left lung, it can be seen that the dose received is greater than the dose received by the right lung, this is because the tumor in this breast cancer patient is on the left side of the breast. For patients 2 and 5 there is no dose distribution to the right lung because the tumor has not spread to the right lung, for patients 1, 3, and 4 the tumor has spread to the right lung.

From the results of data analysis on the left lung, the average OAR value of the left lung at a 15° wedge was 2231.4 cGy, at a 30° wedge it was 2257.8 cGy, at a 45° wedge it was 2141 cGy, and at a wedge angle of 60° of 2059.4 cGy. In the right lung the average dose distribution received at the 15° wedge was 116.2 cGy, at the 30° wedge was 114.6 cGy, at the 45° wedge was 100 cGy, and at the 60° wedge angle was 88.8 cGy. The dose distribution on the four wedges used is still within the permissible limits according to QUANTEC standards, namely less than 2700 cGy (< 27 Gy). It can be concluded that there is no significant difference in the dose received by the left and right lung OAR when using variations in wedge angles of 15°, 30°, 45°, and 60°.

Figure 6 shows a graph of the dose distribution to the heart. For the radiation dose received by the OAR on the heart, researchers took the QUANTEC standard reference, namely less than 2600 cGy (< 26 Gy). From the results of data analysis on the heart, it was obtained that the average heart OAR value at the 15° wedge was 2005.6 cGy, at the 30° wedge it was 2040.4 cGy, at the 45° wedge it was 1930.6 cGy, and at the 60° wedge it was 1844.4 cGy.

The dose received at the four corners of the wedge is still within the permissible limits according to QUANTEC, namely less than 2,600 cGy (<26 Gy). It can be concluded that there is no significant difference in the dose received by the heart OAR when using wedge angle variations of 15°, 30°, 45°, and 60°.

Based on the evaluation that has been carried out on the OAR of the lungs (left and right) and the heart, the dose received still has a safe value according to QUANTEC standards, from the results of the analysis the average value for dose distribution at a wedge angle of 60° has a lower value than the average value for the dose distribution at the 15°, 30°, and 45° wedge for the TPS on the OAR.

IV. Conclusion

Based on the research that has been carried out, it can be concluded that there is a significant influence on the dose received by PTV, while for OAR there is no significant influence on variations in wedge angles of 15°, 30°, 45° and 60°.

Based on data analysis, PTV is optimal and homogeneous at a wedge angle of 15°, while for lung (right, left) and heart OAR the lowest dose distribution is obtained when planning using a wedge angle of 60°.

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