Original Article

The Efficacy of Multi-Leaf Collimator in the Reduction of Cardiac and Coronary Artery Dose in Left-Sided Breast Cancer Radiotherapy

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Abstract

Background: Multi-leaf collimator (MLC) is one of the efficient and cost-effective methods for protecting sensitive tissues around the target. This study aimed to evaluate the protective effect of MLC on the protection of sensitive organs in patients with left breast cancer.

Materials and Methods: This study was performed on computed tomography (CT) scans of 45 patients with left breast cancer. Two treatment plans were completed for each patient. Only the heart and left lung were considered organs at risk in the first treatment plan, and in the second treatment plan, the left anterior descending artery (LAD) was also considered the organ at risk. It was covered as much as possible by the MLC. Dosimetric results of tumor and organ at risk (OARs) were extracted from the dose-volume histogram and compared.

Results: The results showed that more LAD coverage by MLC leads to a significant reduction in the mean dose of OARs (*P*-value <0.05). The mean dose for heart, LAD, and left lung decreased by 11%, 7.4%, and 4.9%, respectively. The values of V_5 (volume received the dose of 5 Gy) and V_{20} for the lung, V_{10}, V_{25}, and V30 for LAD, and V_5, V_{20}, V_{25}, and V_{30} for the heart also decreased significantly (*P*-value <0.05).

Conclusions: In general, better protection of LAD, heart, and lungs can be achieved by maximal shielding organs at risk by MLC in radiation therapy for patients with left breast cancer.

Keywords: Breast neoplasms, cardiotoxicity, conformal, radiotherapy

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Introduction

Breast cancer is one of the most common cancers in the world. About 271,000 new cases of this cancer are reported worldwide each year.[1] One of the treatment methods for breast cancer patients is radiation therapy, in which the preservation of critical organs, including the heart and lungs, is of particular importance.[2] Long-term studies have shown an increase in cardiac risk in patients after radiation therapy, which is proportional to the average dose received by the heart during radiation therapy. Also, cardiac hazards caused by radiation therapy occur several years after treatment.[3,4]

One of the essential mechanisms of radiation-induced heart complications is damage to the heart's arteries. The left anterior descending artery (LAD) is mainly irradiated among the coronary arteries due to its anatomical position, thus reducing its dose is essential.[5,6] Initial set-up such as the prone position of patients, or techniques such as deep inspiration breath

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holding (DIBH), for reducing heart volume in the treatment field, results in a reduction of heart dose.[7,8]

In a study by Testolin *et al*.,[9] using the DIBH technique, the dose reached the heart and LAD were significantly reduced, and also, the maximum dose reached LAD was reported to be 20 Gy. Because applying the DIBH technique requires special equipment or training of patients on how to hold their breath, it is impossible to implement this technique in centers with many patients and limited facilities.

Another method that can reduce the dose of LAD is the heart and LAD shielding using a multi-leaf collimator (MLC). For example, Welsh *et al*.[10] reported using this technique to reduce the mean heart and LAD doses by 23 and 45%, respectively. This study aimed to evaluate the reduction of LAD and heart dose in patients with left breast cancer using MLC shielding to be used as an alternative to the DIBH technique.

Materials and Methods

This study was performed to evaluate the shielding effect of MLC to reduce LAD and heart dose. The current research was investigated retrospectively on 45 patients with left breast cancer who underwent whole-breast radiotherapy after breast conservation surgery between 2019 and 2020. Irradiation with 6 MV photons produced by Siemens accelerator (Primus) was performed to deliver the prescribed dose of 50 Gy in 25 fractions to the whole breast using the tangential radiation field technique.

Image acquisition radiotherapy

All patients underwent a computed tomography (CT) scan (SIEMENS DEFENITION-16 Slice) in the supine position with arms above the head and free-breathing without a contrast agent. These images were imported into the TiGRT treatment planning system.

Target and OARs contouring

The planning target volume was contoured according to the radiation therapy oncology group (RTOG) atlas. The clinical target volume (CTV) includes left breast tissue and lymph nodes. The planning target volume (PTV) was determined according to the instructions of RTOG and by a single radiologist. The PTV was defined by adding a 5 mm margin to the CTV. The contour of the heart, lungs, and LAD as organs at risk (OAR) in breast radiotherapy was delineated according to the heart atlas contouring.[11]

Treatment planning

Two different treatment plans were designed for each patient, including a standard treatment plan (without considering the LAD contour to demonstrate how it is essential to contour LAD by a radiation oncologist) and a treatment plan with LAD shielding using MLC. To create a standard treatment plan, tangential fields were used to maximize breast PTV coverage and minimize heart and lung doses. To optimize the dose of PTV, wedge, and beam weighting were used. In the second plan, more shielding by MLC was used to cover the LAD as much as possible, and no other change was made in the standard treatment plan [Figures 1 and 2]. Finally, the results obtained from the two treatment plans were compared using data extracted from the dose volume histogram (DVH).

Data comparison and analysis

A dosimetric comparison was performed between the two treatment plans. The maximum dose, mean, and other dosimetric factors were compared for all target organs. Also, for comparison of PTV, the homogeneity index (HI) and conformity index (CI) were examined.

The following equations define the CI and HI:

$$CI = \frac{V_{47.5\,Gy}}{V_{PTV}}$$

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

V47.5 Gy represents the volume receiving 47.5 Gy and D2%, D50%, and D98% clarify the doses of 2%, 50%, and 98% of the target volume.

The Statistical Package for Social Sciences (SPSS) version 20 was used for statistical analysis (SPSS Inc. Chicago, II., USA). Independent samples *t*-test was used for comparisons. A *P* value of <0.05 was considered to be significant.

Results

The data obtained from the DVH for the target volume and OAR resulting from two different treatment plans are shown in Tables 1 and 2 and Charts 1 and 2.

According to Table 1, the 95% dose of PTV for the standard treatment plan (plan 1) and the treatment plan in which the LAD was shielded as much as possible (plan 2) was obtained

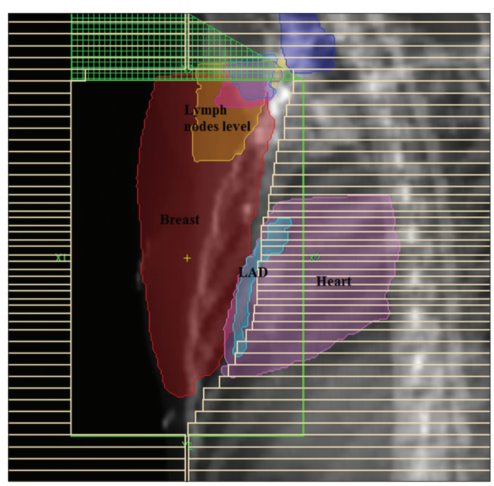

Figure 1: Beam's eye view demonstrating the breast planning target volume

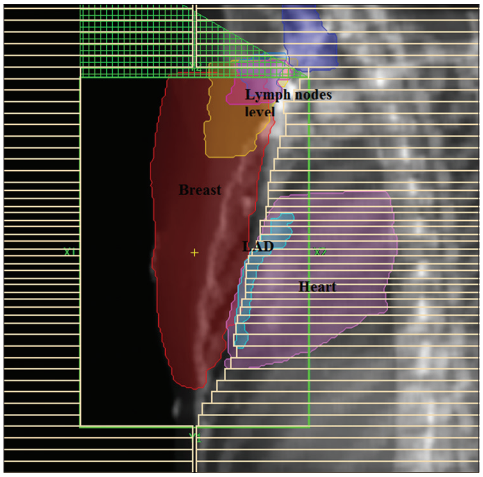

Figure 2: Shielding of the left anterior descending coronary artery (cyan) by MLC

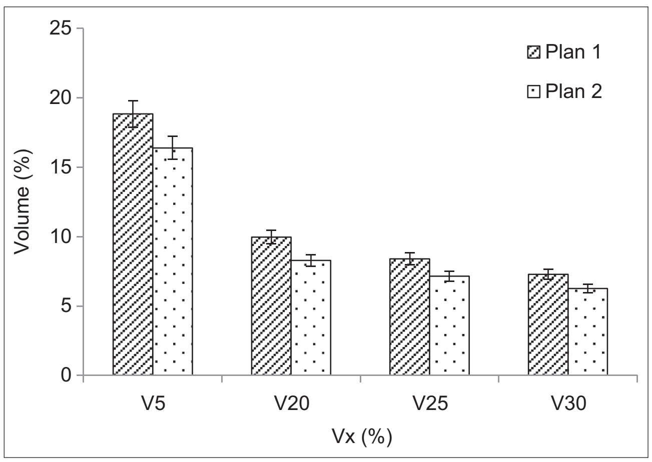

Chart 1: Comparison of dosimetric parameters of heart for plan1 and plan2. Vx is equal to the volume received the x Gy of dose

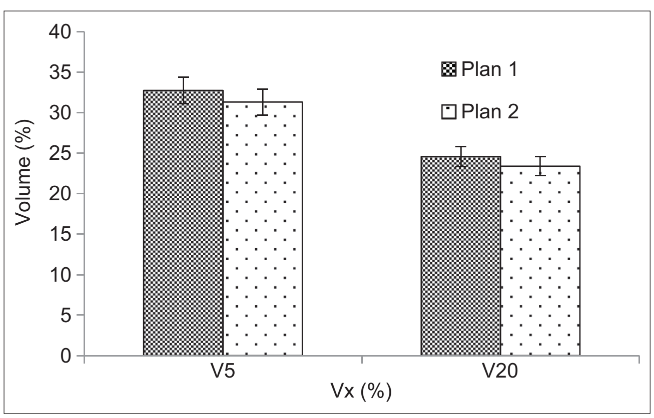

Chart 2: Comparison of dosimetric parameters of left lung for various plans

at 48.46 and 48.35, respectively, which was not statistically significant (*P*-value >0.05).

The mean dose received by the organs can be considered one of the essential dosimetric indicators to compare and determine the coverage of tissue volume. Table 1 provides information on the mean dose of target and OAR with plans 1 and 2. Evaluation of these results indicates a significant decrease in the mean dose of heart, lungs, and LAD in plan 2 compared to plan 1. A comparison of the results of the conformity index (CI) and homogeneity index (HI) shows that there is no statistically significant difference between plans 1 and 2 (*P*-value > 0.05). The CI in plan 1 and plan 2 were 0.97 and 0.95, respectively, and the HI was 0.16 and 0.15, respectively.

Table 1: Dosimetric comparison of mean dose for organs in all 45 breast cancer patients

Organ	Plan 1	Plan 2	*P*
PTV	50.11±0.54	51.12±0.12	0.14
Heart	6.2±2.8	5.48±2.4	0.002
Lung	13.14±0.03	12.5±0.05	0.015
LAD	36.4±10	33.7±10	0.009

Table 2: Dosimetric comparison for LAD between plan 1 and plan 2

Parameters	Plan 1	Plan 2	*P*
D_{max} (Gy)	51.6±2.1	50.1±7	0.6
V_5	90.3±13	87.2±15.1	0.1
V_{10}	84.2±16	78.1±21	0.02
V_{25}	74.2±22	69.1±25.6	0.04
V_{30}	71.2±24	65.3±26.6	0.03

The dosimetric comparison of LAD parameters between different treatment plans is presented in Table 2.

Using the technique of shielding the OAR (plan 2) in this study shows a significant reduction in parameters such as V_{10}, V_{25}, and V_{30} for LAD compared to plan 1. The dose reduction for V_{10}, V_{25}, and V_{30} is 7.2, 6.8, and 8.3 percent, respectively.

As can be seen in Chart 1, the heart dosimetry parameters in plan 2 decreased compared to plan 1, which in all cases showed a significant difference (*P*-value <0.05) so that the dose reduction for V_5, V_{20}, V_{25}, and V_{30} are 13, 17, 15, and 14 percent, respectively.

The dosimetry results of the left lung, including V_5 and V_{20} of different plans, are shown in Chart 2. V_5 for plan 1 and plan 2 are 32.7 and 31.3 mL, respectively, and for V_{20} are 24.5 and 23.3 mL, respectively, which is statistically significant (*P*-value <0.05). Our results also show that the D_{max} values for the lungs in the two different plans were not statistically significant.

Discussion

Reducing the dose of sensitive tissues around the breast, such as the heart, is very important in radiation therapy for patients with left breast cancer to decrease cardiac complications. The results of studies show that despite the remarkable effectiveness of radiation therapy in controlling cancer and increasing survival in patients with breast cancer, there is a possibility of heart disease due to heart substructure fibrosis.[5,12]

So far, various methods have been proposed to reduce the dose of heart and lungs in radiation therapy for breast cancer patients. One of these methods is the DIBH technique, which has provided adequate results. Because the equipment and facilities for performing the DIBH technique are not available in all radiotherapy departments, alternative techniques are used to reduce the dose to the heart arteries.

In this study, which was performed on patients undergoing left breast radiotherapy, the effect of LAD shielding by MLC on dosimetric parameters of the target and different organs at risk, including the heart, lungs, and LAD, was calculated.

The current study results showed a statistically significant reduction in the mean dose of LAD and the heart dose. Moreover, simple shielding of LAD by MLC did not significantly affect PTV dosimetrically.

In a study by Schönecker *et al*.,[13] the heart dose was reduced by 40% using the DIBH technique compared to the FB technique. Also, in this study, the maximum dose of LAD when using the DIBH technique was reduced to 43%. Our results represented fewer values equal to 13% and 3%, respectively.

Lastrucci *et al*.[14] concluded that applying the DIBH technique significantly reduces heart, lung, and LAD doses. The mean dose of the left lung decreased from 6.1 Gy to 4.6 Gy, which was not comparable to our results, giving 13.14 Gy and 12.5 Gy, respectively. The reason for this difference in numbers is that the patients studied in this study underwent a free-breathing CT scan, in which, unlike the DIBH technique, a large portion of the heart and left lung is in the radiation field.

In general, in this study, it was tried that further protection of LAD by MLC did not lead to a reduction in PTV dose coverage. According to the current study results, the coverage dose of the target dose and mean dose of tumor tissue in these two techniques did not show a significant difference (*P*-value >0.05), which is in contradiction with Bartlett *et al*.'s[15] study. They reported a reduction in target volume coverage below 95% in some patients. This difference in the mentioned study with ours could be due to the radio-oncologist decision on compromising for better protection of the heart and LAD or to receive an adequate target dose depending on the patient's condition.

Moreover, according to current results, the amounts of V_5, V_{10}, and V_{30} of LAD were higher than previously reported in another study.[10] This case can be explained by the differences in technical aspects such as characteristics of MLC, the considered margin, and contouring. We used Siemens MLC in our department to shield OARs.

The values V_{20} also decreased significantly under the influence of shielding LAD by MLC in the left lung. A relative reduction of 5% was observed over plan 2. In contrast, Lawler *et al*.[16] concluded that no notable dose differences were observed between FB and DIBH for lungs.

Several studies demonstrated that the use of DIBH leads to a mean heart dose reduction and a reduction in mean, minimum, and maximum doses of LAD.[17-19] However, only a particular group of patients who can follow DIBH protocols are appropriate candidates for using this technique. Moreover, this maneuver is suitable for some departments, which can afford the cost of modern equipment and professional planning skills. However, because a certain threshold has not been reported for the mean dose of heart and LAD, it is necessary to reduce the dose of these organs as much as possible in any medical center. Using the results of this study and further studies in different clinical conditions, a more accurate estimate of the dose evaluation of the heart and its substructure can be achieved.[20]

In conclusion, the results of this study led to a significant reduction in the dose of OARs without any reduction in PTV dose coverage. Therefore, we decided to add a contour of LAD by an oncologist to the protocol in our department for left-sided breast cancer patients.

Conclusion

This current study has demonstrated that the implementation of the MLC shielding technique can reduce the dose of OAR, such as the heart and its substructure and lung, for left-sided breast cancer patients. This technique is a proper alternative method when DIBH is not achievable.

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Conflicts of interest

There are no conflicts of interest.

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