Dosimetry Comparison of Radiotherapy Planning Techniques for Left Breast Cancer

doi: https://doi.org/10.32635/2176-9745.RBC.2023v69n3.4020

Comparação Dosimétrica entre Técnicas de Planejamento de Radioterapia para Câncer de Mama Esquerda

Comparación Dosimétrica entre Técnicas de Planificación de Radioterapia para el Cáncer de Mama Izquierdo

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ABSTRACT

Introduction: Radiotherapy is utilized to treat breast cancer. For radiotherapy planning, there are several ways to develop the treatment plan, such as 3D conformal radiotherapy (3D-CRT), intensity modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT). **Objective:** To compare the doses to risk organs and treatment target volume with different planning techniques, 3D-CRT, IMRT, VMAT and modified VMAT for the treatment of breast cancer in an anthropomorphic phantom. **Method:** The treatment plan was performed in the Eclipse™ v.15.6 system by Varian from CT images acquired from phantom. The established prescription dose was 45 Gy in 25 fractions of 1.8Gy/day. **Results:** For the planning target volume (PTV) coverage, 3D-CRT techniques (FILTER and field-in-field – FIF) showed inferior coverage compared to IMRT and VMAT plans. The 3D-CRT-FIF plan, on the other hand, shows greater homogeneity when compared to 3D-CRT-FILTER. For the contralateral lung, the 3D-CRT plans (FIF, FILTER) have better restrictions when compared with the other plans. On cardiac exposure, the 3D-CRT (FIF, FILTER) plans showed greater benefits when compared with IMRT, VMAT and Modified VMAT techniques. **Conclusion:** Conventional 3D-CRT techniques (FIF, FILTER) showed lower doses in organs at risk. However, IMRT and VMAT techniques obtained better homogeneity and conformity of the dose delivered to the PTV when compared to conventional techniques.

Key words: radiotherapy, conformal; radiotherapy, intensity-modulated; breast neoplasms; radiation dosage.

RESUMO

Introdução: A radioterapia é utilizada no tratamento do câncer de mama. No planejamento radioterápico, há formas de desenvolver o plano de tratamento, como a radioterapia 3D conformacional (3D-CRT), a radioterapia de intensidade modulada (IMRT) e a arcoterapia volumétrica modulada (VMAT). **Objetivo:** Comparar as doses nos órgãos de risco e no volume-alvo de tratamento com as diferentes técnicas de planejamento: 3D-CRT, IMRT, VMAT e VMAT modificada para o tratamento do câncer de mama em um *phantom* antropomórfico. **Método:** O plano de tratamento foi realizado no sistema *Eclipse*™ v.15.6 da *Varian* a partir de imagens de tomografia computadorizada adquiridas de *phantom*. A dose de prescrição estabelecida foi de 45 Gy em 25 frações de 1,8 Gy/dia. **Resultados:** Sobre a cobertura do volume do alvo planejado (PTV), as técnicas 3D-CRT (FILTRO e *field-in-field* – FIF) demonstram cobertura inferior comparada aos planos de IMRT e VMAT. Já o plano 3D-CRT-FIF apresenta maior homogeneidade comparado ao 3D-CRT-FILTRO. Para o pulmão contralateral, os planos de 3D-CRT (FIF, FILTRO) obtiveram restrições melhores em relação aos demais planos. Sobre a exposição cardíaca, os planos 3D-CRT (FIF, FILTRO) apresentaram maiores benefícios do que as técnicas IMRT, VMAT e VMAT modificada. **Conclusão:** As técnicas convencionais 3D-CRT (FIF, FILTRO) apresentaram menores doses nos órgãos de risco. Contudo, as técnicas IMRT e VMAT obtiveram melhor homogeneidade e conformidade da dose distribuída no PTV ao comparar as técnicas convencionais.

Palavras-chave: radioterapia conformacional; radioterapia de intensidade modulada; neoplasias da mama; doses de radiação.

RESUMEN

Introducción: La radioterapia se utiliza en el tratamiento del cáncer de mama. En la planificación de la radioterapia, existen formas de desarrollar el plan de tratamiento, como la radioterapia conformacional 3D (3D-CRT), la radioterapia de intensidad modulada (IMRT) y la arcoterapia volumétrica modulada (VMAT). **Objetivo:** Comparar las dosis en órganos de riesgo y en el volumen blanco de tratamiento con diferentes técnicas de planificación: 3D-CRT, IMRT, VMAT y VMAT modificada para el tratamiento del cáncer de mama en un fantoma antropomórfico. **Método:** El plan de tratamiento se realizó en el sistema Eclipse™ v.15.6 de Varian a partir de imágenes de TC adquiridas del fantoma. La dosis de prescripción establecida fue de 45 Gy en 25 fracciones de 1,8Gy/día. **Resultados:** En cuanto a la cobertura del volumen blanco de planificación (VBP), las técnicas 3D-CRT (filtro - FILTRO y *field-in-field* – FIF) demostraron una cobertura inferior en comparación con los planes IMRT y VMAT. El plan 3D-RCT-FIF mostró mayor homogeneidad en comparación con el 3D-RCT-FILTRO. Para el pulmón contralateral, los planes 3D-CRT (FIF, FILTER) obtuvieron mejores restricciones en comparación con los otros planes. En la exposición cardiaca, los planes 3D-CRT (FIF, FILTER) mostraron mayores beneficios en comparación con las técnicas IMRT, VMAT y VMAT modificada. **Conclusión:** Las técnicas convencionales de 3D-CRT (FIF, FILTER) mostraron dosis más bajas en los órganos de riesgo. Sin embargo, las técnicas IMRT y VMAT obtuvieron una mejor homogeneidad y conformidad de la dosis distribuida en el VBP en comparación con las técnicas convencionales.

Palabras clave: radioterapia conformacional; radioterapia de intensidad modulada; neoplasias de la mama; dosis de radiación.

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INTRODUCTION

Estimates of new cancer cases for 2023-2025 show that the most frequent type in all geographic regions of Brazil will be female breast cancer, and it is also the most frequent in most Federative Units and the Federal District[1]. Based on this scenario, neoplasia represents a challenge for national health, since there are a number of factors that influence the disparity in survival rates in the country, among which is both the delay in diagnosis and the lack of access to treatment [2].

Breast cancer therapy aims to eradicate breast tumor cells and lymph nodes affected by the disease and prevent the recurrence of metastasis. To this end, local therapies can be adopted, such as surgery and radiotherapy, and systemic treatment – which includes endocrine therapy, antibody therapy, as well as chemotherapy[3]. External radiotherapy, or teletherapy, consists of the delivery of a dose by means of a beam of ionizing radiation that originates in a linear accelerator. This energy, in the form of radiation, is deposited on the target, that is, in the treatment volume[4].

Radiation therapy for breast cancer can be performed in the entire breast volume or in a part of it, in the chest wall and in the regional lymph nodes[3]. Neoadjuvant treatment with radiotherapy can significantly improve disease-free survival without reducing overall survival, especially for estrogen receptor positive and early-stage patients[5]. On the other hand, adjuvant radiotherapy demonstrates better locoregional control, and, in addition, brings benefits in overall survival for cases of conservative surgery followed by radiotherapy, regional nodal irradiation and post-mastectomy radiotherapy[6].

When it comes to radiotherapy planning, there are a few ways to develop the treatment plan. One of the conventional embodiments is the *3D* conformal radiation therapy (3D-CRT) technique. This method uses tangential beams with dose compensating filters or overlapping fields to avoid exposure of the ipsilateral lung and the cardiac area[7]. Although treatment with ionizing radiation has benefits in the curability of the disease when reaching tumor cells, the surrounding normal tissue may suffer damage when exposed to radiation causing toxicities[8]. Exposure of the cardiac area to ionizing radiation increases the subsequent risk of coronary heart disease and cardiac mortality[9].

In order to prevent cardiac toxicities intrinsic to radiotherapy treatment, new treatment techniques have emerged, such as intensity-modulated *radiation therapy* (IMRT) and *volumetric modulated arc therapy* (VMAT)[10]. Both enable precise dose delivery by decreasing target volume margins and improve the conformation of the energy deposited in the treatment volume, when compared to the conventional modality[11].

The VMAT technique can be used to spare organs from risk – or organ at risk (oar) in English – such as the cardiac area[10]. However, its application should be discussed in cases with an increased lung dose[12], which may be associated with a higher risk of secondary cancer in the contralateral breast[13]. This is due to the spread of ionizing radiation reaching the contralateral breast tissue, which is radiosensitive[14].

In breast treatment, the VMAT technique delivers the dose from two partial arcs, in opposite directions (clockwise and counterclockwise)[13-15]. Considering the specificities in relation to the pulmonary dose and the contralateral breast in the application of this technique, the research presents the analysis of a variation of it, a resource used routinely in the institution where the study was performed, called modified VMAT (VMATMOD), which is characterized by the division of the two partial arcs into four partial semiarch in the delivery of the dose during the rotation of the *gantry* on its axis.

It is known that the choice of the treatment technique used in radiotherapy for breast cancer should be made individually based on the balance between the risks and benefits of the modality, also considering the anatomical characteristics of the patient that may influence the selection of the ideal technique[14]. Based on this scenario, the study aims to compare the doses in the oar and in the target volume of treatment with the different planning techniques: 3D-CRT, IMRT, VMAT and VMATMOD for the treatment of breast cancer in an anthropomorphic *phantom*.

METHOD

The treatment plans of the 3D-CRT, IMRT, VMAT and VMATMOD techniques for the study of breast radiation dose delivery were carried out through the acquisition of tomographic images (*Hi-speed equipment,* GEbrand, *64-channel multislice*) from an anthropomorphic object (*phantom*) in elliptical form, which simulates the anatomy of a human trunk of medium height. Considering that the study and data collection were carried out from images of a *phantom, therefore,* without the involvement of human beings, the research does not require the approval of the Ethics Committee in Research with human beings. *Digital Imaging and Communications in Medicine* (DICOM) images spaced 1.25 mm between axial sections were inserted into the *Eclipse* planning system (Varianversion™ V.15.6, calculated with the anisotropic analytical algorithm – AAA).

For the design of the oar and the planned *target volume* (PTV), the recommendations of the anatomy atlas of the *Radiation Therapy Oncology Group* (RTOG) were followed. Both the volume of the clinical target – or *clinical target volume* (CTV) –, which encompassed the entire breast tissue and the chest wall, as well as the PTV were represented by the left breast. The following oar were delineated: ipsilateral lung, contralateral lung, spinal cord, contralateral breast, esophagus, ribs, lymph node chain of the internal mammary and cardiac area (Figure 1).

The established prescription dose was the conventional 45 Gy fractionation regimen in 25 fractions of 1.8 Gy/day. For the IMRT and VMAT/VMATMOD planes, a structure was delineated between the breast and the region of the chest wall with a thickness of 1 cm called "ring" (in green color) in order to reduce doses in the ipsilateral lung, as shown in Figure 1. Plans were calculated for treatment on the *TrueBeam® Stx HD* linear accelerator (0.25 mm blades in the isocenter region), with energy of 6 MV and dose rate of 600 MU/min.

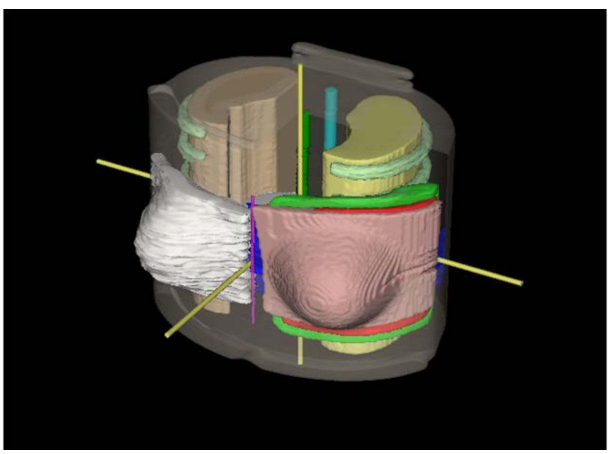

Figure 1. Design of risk organs and target volume

After the design of the oar and PTV, the isolated treatment techniques were planned in the following order: 3D-CRT (FILTER *and* field-in-field – FIF) , IMRT, VMAT and $_{\text{VMATMOD}}$. The evaluations of the restrictions were guided by the recommendations of the *Quantitative Analyses of Normal Tissue Effects in the Clinic* (QUANTEC)[16] and RTOG[17].

In the 3D-CRT planning, we opted for medial (306°) and lateral (133°) tangent fields, with multi-blade collimators and angulations chosen in order to minimize the dose in the pulmonary area and contralateral breast as recommended in the 3D-CRT routine. The 3D-CRT-FIF plane used the FIF technique for dose homogenization, while the 3D-CRT-FILTRO plane applied 45° wedge-shaped compensating filters to obtain dose control on the surface. In the IMRT plane, the *sliding-window* technique with six *gantry* angles (306°, 150°, 330°, 0°, 30° and 90°) was chosen. The VMAT plane was elaborated from two partial arcs, with the following arrangement: angle from 306° to 150° clockwise, and angle from 150° to 306° counterclockwise.

For the planning of the VMATMOD technique, the isocenter was displaced in the region close to the costal arches, so that four blocked semi-arches excluded the divergence of the radiation beam in the volume of the ipsilateral lung. The semi-arches are arranged at the following angles: 306° to 45° clockwise, 45° to 150° clockwise, 150° to 45° counterclockwise and 45° to 306° counterclockwise. In the IMRT, VMAT and VMATMOD plans, the dose constraints for the target volume and the oar were used in the optimization of the plans (IMRT and VMAT/VMATMOD), as described in Table 1.

Table 1. Dose restriction for treatment plans

PTV/oar	RESTRICTION DOSE
PTV	D100% ≥ 45 Gy
Cardiac area	V5 Gy ≤ 40%
	V25 Gy≤ 10%
Ipsilateral lung	V5 Gy ≤ 60%
	V20 Gy ≤ 30%
Contralateral breast	D_{MAX} ≤ 1.8 Gy

Captions: PTV = planned target volume; oar = risk organs; V = volume receiving the indicated doses; D = dose; Gy = gray.

RESULTS

The evaluations of treatment plans in the left breast involve qualitative and quantitative analyzes of isodose distributions in PTV and oar. In Figure 2, it is observed that the dose distributions of 500 cGy (represented by the blue color) in the 3D-CRT techniques (FIF, FILTER) are restricted to the bottom line of the tangential fields and very close to the PTV, that is, a minimum spread of these low doses is noted. However, the IMRT, VMAT and VMATMOD techniques have a higher distribution of low doses (500 cGy represented by the blue color) in other adjacent tissues, such as ipsilateral lung, cardiac area and contralateral breast.

Among the criteria for evaluating the plans, the homogeneity index (HI) of the dose distributions was analyzed, which is recommended to be close to zero[18,19]. Another criterion establishes the compliance index (CI) of dose distributions between 0.95 and no greater than[18-20]. Table 2 shows the values of the HI calculations, which showed a variation of 5% to 7% in the target volume, showing an acceptable uniformity correlation. Also in Table 2, in the analysis for the IC calculations on the target volume, there was a variation from 1.02 to 1.182, acceptable limits. Therefore, the IH and IC values

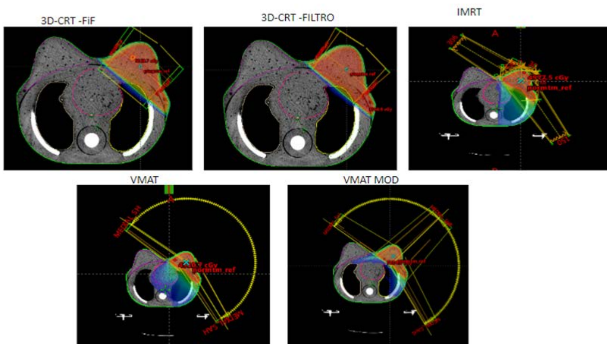

Figure 2. Comparison of isodose curve distribution

obtained for all treatment techniques are in accordance with the established parameters.

For the purpose of equal comparisons between the techniques, the criterion was established in which the isodose curve was defined by D95%, that is, the volume of 95% of the PTV should receive 100% of the prescribed dose. Regarding PTV coverage, it is observed that all techniques demonstrate satisfactory and acceptable coverage. The 3D-CRT-FIF technique proved to be advantageous for maintaining the acceptable dose gradient compared to the other planes, due to the modulation criteria adopted for this technique when compared to the 3D-CRT-FILTRO technique. Unlike the techniques that use inverse planning (IMRT, VMAT, $VMATMOD_{)}$, the same optimization parameters (constants) were used in these, without forcing the system to achieve improvements in planning. Table 3 shows the dosimetric evaluation of the treatment plan that contains a quantitative analysis of the oar with the description of the dose restrictions between 3D-CRT-FIF, 3D-CRT-FILTRO, IMRT, VMAT and VMATMOD.

The results of the 3D-CRT technique (FIF, FILTER) show lower doses in the ipsilateral lung, contralateral breast and cardiac area. Regarding the exposure of the cardiac area, the 3D-CRT planes (FIF, FILTER) showed greater benefits when compared with the IMRT, VMAT and VMATMOD techniques. The RTOG restriction recommendation recommends that the average dose in the cardiac area be 4 Gy. IMRT and VMAT plans exceeded the mean dose limit in the cardiac area, only VMATMOD presented the permissible dose threshold as shown in Table 3. The fact demonstrates the superiority of the technique when comparing it with IMRT and VMAT, since the same parameters were used without forcing optimization.

For the contralateral lung, the 3D-CRT planes (FIF, FILTER) obtained acceptable restrictions when comparing with the other planes and the restrictions of the RTOG. In the IMRT plan, the ipsilateral lung presented a V5 Gy of 66.96%, contrary to the recommendation that the V5 Gy should be at most 60%. For the ipsilateral lung, the VMATMOD plan showed better results in the maximum dose and V20 Gy criteria compared to IMRT/VMAT techniques. The VMAT presented the highest dose contribution in the spinal cord, due to the arrangement of the arches. However, in the VMATMOD proposal, there was a reduction of about 59% of the dose in the spinal cord.

Due to the concern about the likelihood of radio induced cancer after radiotherapy treatment, radiation requires monitoring of this dose, since the contralateral breast is a radiosensitive tissue. The RTOG recommends that the maximum dose in the contralateral breast does not exceed the limit of 3.10 Gy. Comparing the maximum dose values of the contralateral breast between the planes, the 3D-CRT techniques (FILTER and FIF) resulted in acceptable limits depending on the configuration of tangential fields. Among the reverse planning techniques, IMRT was the one that resulted in a higher dose contribution in the contralateral breast, followed by VMATMOD, which showed better efficacy in minimizing doses in the ipsilateral lung and in the cardiac area. The VMAT technique presented the lowest dose in the contralateral breast among the reverse planning techniques, but it did not have the same success in the other oars (such as ipsilateral lung, cardiac area and spinal cord).

Table 2. Quantitative dosimetric analysis of PTV

PTV	3D-CRT-FIF	3D-CRT-FILTRO	IMRT	VMAT	$VMAT_{MOD}$
D95% (cGy)	4.500	4.500	4.500	4.500	4.500
Dmean (cGy)	4,671.9	4,660.6	4,646.6	4,651.2	4.660
Dmax (cGy)	4,821.8	4,815.2	4,882.7	4,836.2	5,016.5
Prescription curve	89%	97 %	102.5%	103%	102.5%
Conformity index	1.02	1.037	1.163	1.182	1.149
Homogeneity index	0.06	0.05	0.06	0.06	0.07

Captions: PTV = planned target volume; 3D-CRT-FIF = field-in-field conformational 3D radiotherapy; 3D-CRT-FILTRO = FILTER conformational 3D radiotherapy; IMRT = intensity modulated radiotherapy; VMAT = modulated volumetric arc therapy; VMATMOD = modified VMAT; D = dose; cGy = centigray.

Table 3. Dosimetric comparison in different treatment plans

OAR	Parameters dosimetric	3D-CRT-FIF	3D-CRT-FIF FILTER	IMRT	VMAT	$VMAT_{MOD}$
Lung contralateral	Dmax (cGy)	5,2	11.9	759.9	841.5	1,161
	V5 Gy (%)	0	0	1.44	3.32	10
Lung ipsilateral	Dmax (cGy)	4,240.1	4,274.5	4,232.5	4,386.9	4,471.2
	V20 Gy (%)	2.48	2.38	23.68	15.74	5,61
	V10 Gy (%)	3,68	3,78	50.57	43.72	20.79
	V5 Gy (%)	7,6	6,95	66,96	75,34	50,90
Spinal Cord	Dmax (cGy)	0	0	491.3	584.1	203.6
Cardiac area	Dmax (cGy)	3,887.9	3,921.2	3,977.4	4,425.4	3,039.7
	DMed (cGy)	105.3	113,9	929.6	1,308.2	402.2
	V25 Gy (%)	0.03	0.03	5.27	5.71	0.47
	V15 Gy (%)	0.15	0.09	22.91	31.05	3.05
	V5 Gy (%)	2.03	1.41	57.96	41.52	20.80
Contralateral breast	Dmax (cGy)	26.1	38.6	830.4	458.8	1,055.1
		0	0	10.75	3	4.6

Captions: oar = risk organs; 3D-CRT-FIF = field-in-field conformational 3D radiotherapy; 3D-CRT-FILTRO = FILTER conformational 3D radiotherapy; IMRT = intensity modulated radiotherapy; VMAT = modulated volumetric arc therapy; VMATMOD = modified VMAT; D = dose; cGy = centigray; V = volume receiving the indicated doses.

DISCUSSION

In order to reduce intrinsic toxicities to radiotherapy, it is suggested the applicability of different treatment techniques, such as 3D-CRT using FIF, multi-field IMRT and VMAT[21]. The results in relation to the technique that presents the greatest benefit are divergent between the studies. When comparing the 3D-CRT-FIF technique with IMRT for patients treated with post-mastectomy radiotherapy in the left chest wall, Aras et al.[22] highlighted that IMRT resulted in a plan with greater dose compliance, and with dose reduction in the ipsilateral lung and heart, while the 3D-CRT-FIF technique was superior in terms of low dose volume. In contrast, Elzawawy and Hammoury[23] concluded that 3D-CRT-FIF has lower doses in the lung, contralateral breast and heart, in addition to sub volumes such as the coronary artery compared to the IMRT technique. Supakalin et al.[24] state that the IMRT and VMAT techniques present cardiac doses within the V30 Gy tolerance limit below 10%. However, although the VMAT demonstrates excellent homogeneity and compliance in the isodose curves, the technique results in a significantly higher dose in the contralateral breast, similar to that found in the present study.

The selection of the planning technique is an essential aspect in the therapeutic process. Therefore, it is necessary to consider the individual characteristics of each patient, such as anatomy[25], in order to ensure the coverage of the target and minimize the exposure of the rag. In this study, all treatment plans received 100% of the dose prescription and there was little variation in the target volume D95% (cGy), as it is a *phantom* with favorable anatomy. In practical cases, PTV D95% (cGy) presents significant differences when comparing treatment techniques[26].

The HIs that presented values close to zero demonstrate excellent coverage in PTV. In the study, the values ranged from 0.04 (3D-CRT-FIF) to 0.105 (3D-CRT-FILTRO)[27]. CIs that approach 1 represent a good quality in dose distribution. In this study, values ranged from 1.02 (3D-RCT-FIF) to 1.182 (VMAT)[27]. The results are similar to those of Supakalin et.al. 24 in their study, which analyzed different techniques for planning radiotherapy for breast cancer after conservative surgery, which obtained an HI of 0.755 for VMAT and 0.636 for IMRT; on the other hand, the CI was 0.876 for VMAT and 0.728 for IMRT.

One of the most worrying late toxicities is cardiac, since exposure of the heart during radiotherapy is inevitable, especially in cases involving irradiation of the left breast[8]. Exposure results in a variety of toxicities by inflammatory pathways depending on the exposed cardiac substructure[28]. For cases of left breast cancer, the left anterior descending artery (lad) and the left ventricle are more exposed to radiation doses than other cardiac sub volumes[29]. This is worrying because lad is the largest coronary artery and carries half of the myocardial blood supply[30]. Therefore, damage to any portion of the structure can cause severe ischemic heart disease[29]. This fact is in addition to the use of other associated therapies for breast cancer that are also cardiotoxic, such as anthracyclines and HER2[31] antagonist drugs.

Regarding pulmonary toxicity, radiation-induced pneumonitis is the main effect of radiotherapy. It is an inflammatory state in which some factors predict its development, including age greater than or equal to 64 years, pulmonary comorbidities, concomitant chemotherapy, as well as the technique of radiotherapy applied and higher doses[32]. Regarding pulmonary doses, Chao et al.[33] compared the IMRT and VMAT modalities. The result showed that the VMAT presents satisfactory pulmonary doses when comparing it with the IMRT technique.

Due to radiation exposure, the contralateral breast is likely to develop secondary cancer[34]. However, this is influenced by the patient's anatomy, there is a variability in the doses of the contralateral breast due to the differences between the minimum distance of the contralateral breast in relation to the breast that will be treated, and with each increase of 1 cm of this distance, the average dose of the contralateral breast decreases about 10% to 15%[35].

CONCLUSION

From the analysis of the results, it is concluded that the conventional 3D-CRT techniques (FILTER and FIF) presented lower doses in the OAR. However, the IMRT, VMAT, VMATMOD techniques obtained better homogeneity and conformity of the dose delivered in the PTV in relation to conventional techniques. The dose distributions within the limits of the PTV in the treatment plans are related to the favorable anatomy of the breast, in this case, the *phantom object.* In clinical routine conditions, the most diverse types of anatomy are found, requiring the use of complex techniques with reverse planning, among which VMATMOD stands out to achieve lower doses in the cardiac area and in the ipsilateral lung.

In the results of this research, the gradients of the IMRT/VMAT /VMATMOD techniques presented higher values than those of the traditional techniques (3D/FIF), however, it is noteworthy that the occurrence is justified by the same use of optimization parameters of the inversely modulated techniques. Since better results are possible due to the adjustment in the system to optimize the plan by adding criteria of greater restrictions, as well as the use of auxiliary structures in the design.

Considering that the objective of the research was to correlate the different techniques, it was decided not to adjust the planning system in order to reoptimize the plan of the treatment techniques that are acquired from the reverse planning, in the case of IMRT and VMAT. Therefore, the variability between dose gradients, hot spots and dose in the rag was assumed as a result, since no criteria of greater restrictions and auxiliary structures were added in the design for optimization.

The VMATMOD technique is a resource used routinely in the institution, it basically differs from the traditional VMAT due to the asymmetry of the collimators, with one of them completely closed, thus avoiding the divergence of the radiation beam in the OAR, ipsilateral lung and cardiac area, for example.

The results of the research serve as an informative basis on the doses in the oar and target volume, providing data to establish a criterion of choice for defining the ideal technique depending on the anatomy of the patient for the treatment of external radiotherapy in breast cancer.

ACKNOWLEDGEMENTS

To the CORB radiotherapy service in Blumenau, in particular, to the Department of Medical Physics, under the supervision of the physician-physician Herofen Zaias, who developed the anthropomorphic simulator used in the study.

CONTRIBUTIONS

Tatiane Mayla Domingos Prandi, Herofen Zaias, Charlene da Silva and Patrícia Fernanda Dorow contributed substantially to the design and/or planning of the study; data collection, analysis and interpretation; writing and critical review. Juliana dos Santos Müller and Larissa Palhano da Silva Blasius contributed to the writing and/or critical review. All authors approved the final version to be published.

DECLARATION OF CONFLICT OF INTERESTS

There is no conflict of interest to declare.

FUNDING SOURCES

None.

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Recebido em 8/5/2023
Aprovado em 20/6/2023

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