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# Influence of the breast prosthesis volume in dose distribution in radiotherapy planning

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## ABSTRACT

**Introduction:** The challenge of modern radiotherapy (RT) in breast cancer is to maintain its satisfactory oncological results, adapting to oncoplastic surgery and avoiding possible cosmetic damage. Considering that the breast prosthesis is not a target volume in RT planning, this study sought to analyze the effect of this volume on the coverage of the clinical target volume (CTV) of the breast. **Methods:** We performed a retrospective analysis of plans in 48 patients who submitted to RT in the first half of 2014. Two volumes were measured, such as breast CTV (breast tissue with the prosthesis) and real CTV (breast tissue excluding the prosthesis). The D95% values (dose that covers 95% of the volume) for each of them were verified and related to the volume of each one as well as the volume of breast prosthesis. **Results:** The analysis of the CTVs showed a significant difference between the mean volumes for the real CTV and breast CTV. While performing the CTV coverage, including the prosthesis, there is a perception that the dose covered 95% of the volume. Nevertheless, the analysis of the same plan after prosthesis volume exclusion revealed a difficulty in covering 95% of the breast tissue volume, indicating the interference of the prosthesis in therapy planning. Considering the dosimetric aspects, there were patients with real CTV values below the ideal dose of 47.5 Gy, after exclusion of implant volume. **Conclusions:** Our data reflected the volume of the prosthesis as an important variable that should be considered when planning adjuvant RT.

KEYWORDS: radiotherapy; breast neoplasms; breast implants; mammaplasty.

## INTRODUCTION

Breast cancer (BC) is the most incident cancer with high mortality among Brazilian women. Globally, in 2018, it caused 670,000 deaths, of which 17,763 deaths were estimated in Brazil, including 17,572 women and 189 men[1,2].

Surgery, the conventional treatment for BC, has been evolving throughout the years. In the 19th century, Halsted[3] introduced the radical mastectomy, which was gradually replaced by the modified radical mastectomies with muscle preservation, developed by Patey[4] (1948) and Madden[5] (1972). In 1981, Veronesi et al.[6,7], followed by Fisher et al. in 1985[8], demonstrated that conservative treatment of BC followed by adjuvant radiotherapy (RT) had the same efficiency than that of mastectomy, considering overall survival rate. However, despite conservative treatment has been considered a conventional treatment (standard of care), the mastectomy still needs to be considered in many cases[8,9].

The introduction of plastic surgery techniques in oncology originated the term "oncoplastic surgery," aiming to integrate good oncological control, with favorable cosmetic results. Reconstructions are often used in postmastectomized women, including the insertion of breast implants, expanders, and autogenous tissues (i.e., TRAM, latissimus dorsi)[10,11]. This practice in mastology encompasses not only conservative treatments but also techniques involving immediate postmastectomy reconstruction, which can be either skin-sparing mastectomy type or nipple-sparing mastectomy[12,13].

RT can be considered as an adjuvant treatment option in patients with mastectomy. The indication for this treatment, called postmastectomy RT (PMRT), is based on the probability of local and regional failure in the case of isolated radical surgery[14]. Adjuvant RT can improve the rates of locoregional control, specific cancer survival, and also overall survival[15-18]. To perform the PMRT, prior planning is necessary in which the clinical treatment

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volume (clinical target volume [CTV]) is defined. CTV is the volume of tissue that may contain the microscopic disease and/or gross subclinical disease[19,20].

After defining the treatment volume, it is necessary to analyze the dose that will be absorbed by it, which is defined as the measure of the biological effects produced by ionizing radiation. This analysis is performed using the dose and volume histogram (DVH) and presents the ratio of absorbed dose per volume of analyzed tissue[21].

Most breast RT guidelines include breast implants as a treatment volume; however, breast implants are not a volume of interest for RT[22]. Considering that the prosthesis material does not contain tumor cells, the present retrospective study evaluated whether the dose distribution (D95%) in the CTV can be better evaluated by excluding the prosthesis volume in the calculation of the total volume to be treated.

## METHODOLOGY

In this retrospective study, 48 plans of patients treated with RT in the first half of 2014 were evaluated. The inclusion criteria were as follows: women above 18 years, with breast reconstruction, and with the indication of RT (postmastectomy radiation). Forty-six patients had subcutaneous implants, while two patients had subpectoral implants. All cases were planned based on the three-dimensional conformal technique and, for each plan, the D95% values (dose covering 95% of the target volume) were analyzed for the breast CTV (breast tissue with the prosthesis) and the real CTV (breast tissue excluding the prosthesis). To exclude the prosthesis volume from breast CTV, we used the Boolean operation. The prescribed dose for all cases was 50 Gy in 25 fractions, with 6-MV linear accelerator beams. To avoid the buildup effect (the peripheric zone of the body where the radiation has some instability and the delivered dose is not uniform), we have used a Boolean operation to subtract a distance of 0.5 cm of skin.

Dose distribution was evaluated slice by slice of images, and DVH analysis was performed to ensure that recommended doses would cover 95% of the target volume (D95%). Based on the study by the Radiation Therapy Oncology Group 1005 protocol, 47.5 Gy was considered the ideal dose and 45 Gy was considered the acceptable dose for D95%[23].

All dose distributions were considered based on breast CTV, real CTV, and prosthesis volume, aiming to verify the correlation among them.

The planning used to calculate the treatment doses was Eclipse v. 8.6 (AAA, Varian Medical Services). For the analysis of statistical correlation between variables, nonparametric tests were used (t-test, Wilcoxon test, and Spearman's rho) and the established significance level was 95%.

Considering the retrospective and dosimetric characteristics of this study, it did not change the original prescriptions and doses delivered to the patients.

This study was approved by the Research Ethics Committee (11787219.5.0000.5437) of Barretos Cancer Hospital.

## RESULTS

From the 48 analyzed plans, 27 plans corresponded to left breasts and 21 plans corresponded to right breasts. Figure 1 contains a representative image of CTV delimitation, showing the delineation of the created volumes of breast CTV (including the volume of the prosthesis), real CTV (excluding the volume of the prosthesis), and the volume of the prosthesis alone.

From the measured volumes of 48 patients, the mean, maximum, and minimum volumes of CTV values for the total (breast CTV) and real (real CTV) breasts were determined. The distribution analysis of measured volumes showed a significant difference between the mean volumes for the real CTV and the breast CTV, the latter being significantly higher (Figure 2A). The means of these values, as well as the mean value of the prosthesis, are shown in Figure 2B, which highlights the difference between real CTV and breast CTV ($p<0.001$).

The D95% values were determined based on measured volumes. The dose histogram and volume shows the dose distribution curve for the CTV for one randomly selected patient, containing the dose curve for the real CTV (orange) and the breast CTV (red), as shown in Figure 3A. It is possible to observe a shift of the curve to the left when the volume of the prosthesis is excluded for the calculation of D95%, indicating that the value of D95% for breast CTV is higher than for real CTV. The coverage of the breast shows the dose distribution over the reconstructed breast, as shown in Figure 3B. It is important to observe the two underdosage areas, one just below the skin (buildup effect, denoted by orange arrows) and the other in depth (intersection of the prosthesis with the chest wall, denoted by blue arrow).

These data are corroborated by the graph showing the distribution of points, with a significant increase in D95% for breast CTV (Figure 3C). The mean D95% values for breast CTV (red curve) and real CTV (orange curve) were 48.2 Gy (94.5% of the total dose) and 49.2 Gy (93% of the total dose), respectively (Figure 3D). There were no significant differences considering the prosthesis volume and laterality (left or right breast, $p<0.0001$).

Despite the mean D95% of the real CTV being within the ideal dose limits, considering the distribution of volumes for all patients, the values of the real CTV included points below the ideal dose of 47.5 Gy. Furthermore, it can be observed that there was a value of 44 Gy, below the acceptable dose of 45 Gy. These data reflect the importance of considering the exclusion of breast implants in the assessment of a conformational plan, which is a relevant dosimetric information.

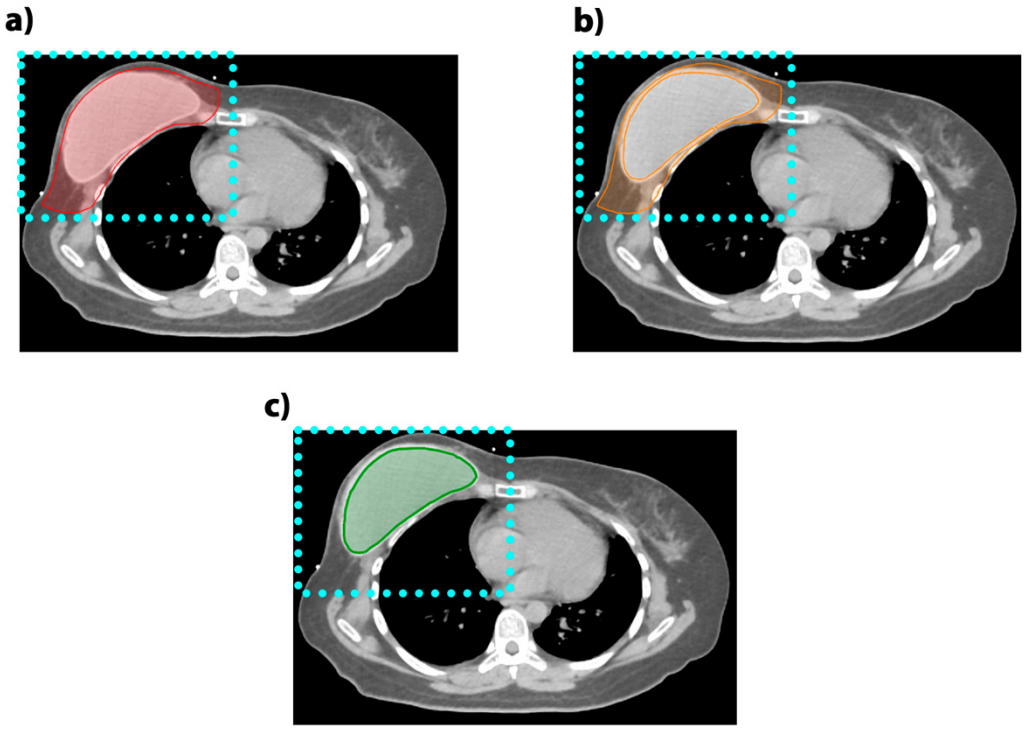
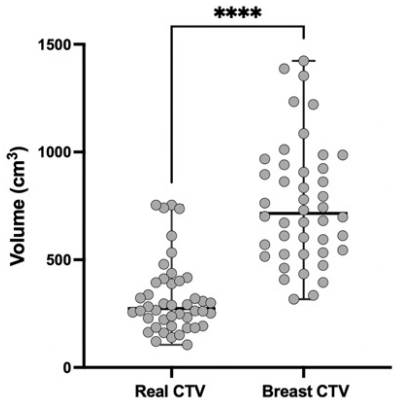



**Figure 1.** Delimitation of (A) total breast CTV (red area), (B) real CTV (orange area), and (C) prosthesis volume (green area). These volumes were designed for all patients in this study. The retraction observed right under the skin is due to the buildup effect zone.




b)

| Calculated volumes for Real CTV, Breast CTV and Prosthesis ($cm^3$) | | | |
|---|---|---|---|
| | Mean | Maximum | Minimum |
| Real CTV | 315,2 | 754 | 105 |
| Breast CTV | 750,3 | 1423 | 317 |
| Prosthesis | 434,5 | 821 | 104 |

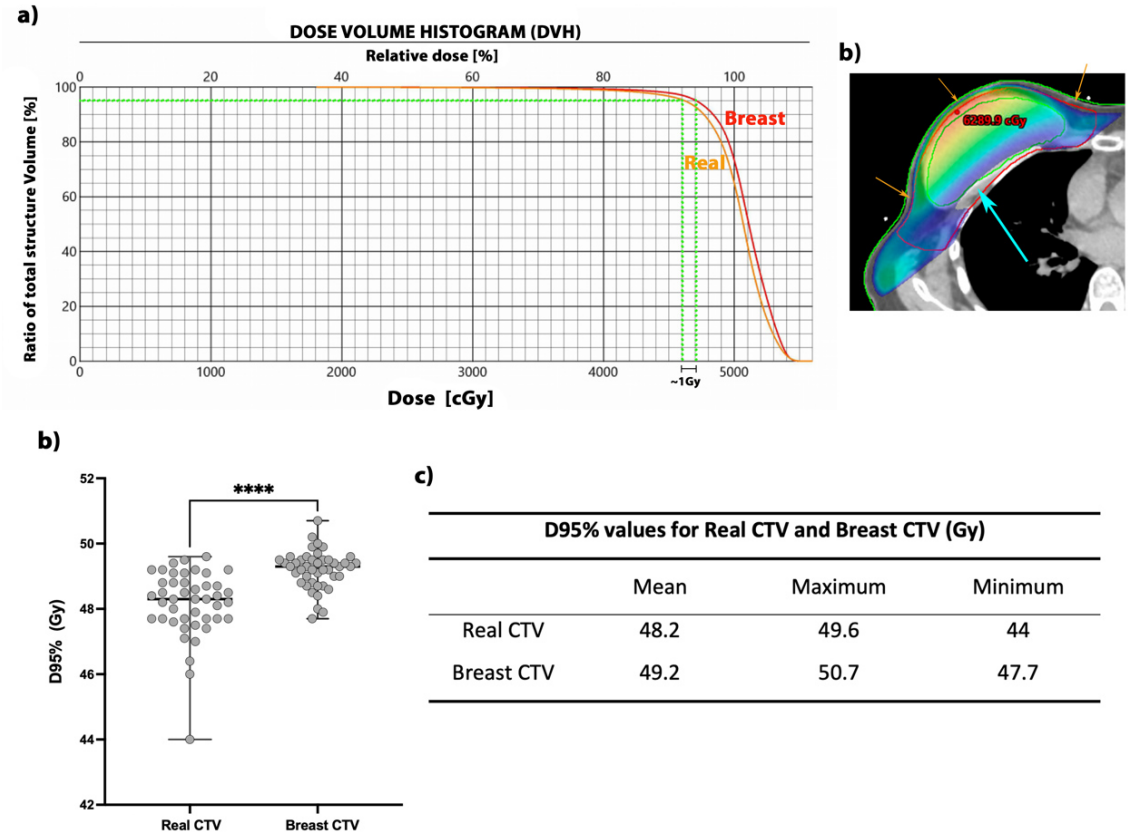
**Figure 2.** Influence of the prosthesis volume on CTV determination. (A) Graph showing the distribution of CTVs determined for real and breast CTVs, with a significant difference of volumes when considering prosthesis in the calculation of CTV. (B) Average, maximum, and minimum volumes collected for patients. P<0.0001.

## DISCUSSION

Immediate breast reconstruction is an attractive procedure for patients undergoing mastectomy. Ideally included in the overall treatment of the patient, this practice brings the benefits of reducing psychological trauma, more favorable cosmetic effects, lower cost, and reduced morbidity related to surgery[24,25]. However, RT treatment after breast reconstruction may compromise the cosmetic effect[26,27].

Despite the impact of PMRT in breast reconstruction, this approach has been shown to be beneficial to patients, by preventing tumor recurrence[24]. The main goal, in this case, is to reduce the risk of locoregional recurrence, prolong the patient's survival, and reduce the secondary spread of the tumor[25].

Considering the PMRT in reconstructed breasts, the literature lacks information about the effect of the prosthesis in the planning and delivery of RT, which is a relevant factor considering the evolution of planning in RT[25]. The main focus explored in published papers is directed to organs at risk protect strategies, such as the heart and lung[25,28]. Other considered factors are




**D95% values for Real CTV and Breast CTV (Gy)**

| | Mean | Maximum | Minimum |
|---|---|---|---|
| Real CTV | 48.2 | 49.6 | 44 |
| Breast CTV | 49.2 | 50.7 | 47.7 |

**Figure 3.** Effect of CTVs on D95%. (A) Comparative graph showing the difference of D95% determined for the real CTV and breast CTV. (B) Curve of 50-Gy coverage for breast. The subdosage breast tissue areas are pointed out by the orange (under the skin) and blue (intersection of the prosthesis with the chest wall) arrows. Meanwhile, the prosthesis is almost entirely covered (area delimited by green area). (C) and (D) Mean, maximum, and minimum values were obtained for the real and breast CTV groups. P<0.0001.

the complications that lead to the need for excision and loss of the prosthesis[14]. Given this scenario, scientists have questioned whether RT after reconstruction would be the ideal approach, but a study presented by Allué et al. in 2019 showed that RT before reconstruction brought higher risks of failure when compared with patients who received the postreconstruction treatment[29].

Clinical results show that breast reconstruction can affect RT planning. In this context, an adequate and precise planning, which will be able to differentiate the real tissue that receives the RT dose, can be helpful for the reduction of problems related to PMRT. It is of critical importance for the radiation oncologist to assess the breast anatomy to define the residual breast tissue that may harbor microscopic cells. Depending on the placement of the tissue expander/implant in the prepectoral or subpectoral space, microscopic cells may remain anterior and/or posterior to the expander/implant. This is of even greater importance in the setting of close or positive surgical margins in the postmastectomy setting when dose distribution and assurance of adequate dose in the areas of greatest concern for microscopic residual may need to be factored into treatment planning. In such scenarios, bolusing of the skin to improve superficial dose and/or boosting in the postmastectomy setting may be considered. This analysis confirms that the inclusion of the prosthesis volume in dose coverage analyses may falsely indicate that adequate dose is being achieved. A more detailed DVH assessment excluding the prosthesis volume serves to better ensure adequate coverage of the true breast tissue at risk of harboring microscopic cells and may inform decisions regarding the need for bolus and/or boost to achieve coverage goals.

In this study, we demonstrated that the exclusion of the breast implant in the assessment of D95% in the target volume during RT planning can interfere with coverage, considering that the implant itself does not represent a target to be treated. The real CTV, excluding the prosthesis volume, showed a difference in the D95%, highlighting that the prosthesis/breast volume ratio can be a factor to overestimate the coverage of the target. The practical effect that this information reveals is that even though there is complete coverage of the area to be treated, the

D95% related to the actual CTV is actually lower, implying less coverage than necessary. Considering the dosimetric aspect, two regions of underdosage are expected—one just below the skin (buildup effect) and the other in depth (intersection of the prosthesis with the chest wall). This is a common effect in the 3D-RT technique and is related to the buildup effect (in the peripheric region), with the longer traveled radiation pathway in the depth zone. It is worth to mention that upon exclusion of prosthesis volume, those regions may become more evident.

Despite the mean value of D95% being within acceptable limits, we observed the values below 47.5 Gy, including one patient below 45 Gy. Thus, the exclusion of breast implants in the evaluation of a plan can be a relevant dosimetric information. Less number of patients and lack of correlation with clinical data are the limiting factors of this study, but the evidenced dosimetric implications can be valuable data for future clinical approaches. In this way, studies including a larger number of patients and correlating the dosimetric implications with the clinical effects in disease control and toxicity are necessary. Its application in clinical practice should be better investigated with studies to check whether this form of assessment interferes with local recurrence rates, overall survival, and specific BC.

## CONCLUSIONS

In this study, we evaluated the influence of excluding the volume of the prosthesis in determining the CTV, and the effect reflected in the D95% values in patients with postmastectomy, with breast reconstruction and submitted to RT. Our data reflected the volume of the prosthesis as an important variable that should be considered when planning adjuvant RT.

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## AUTHORS' CONTRIBUTIONS

P.V.F.: Data curation, Formal analysis, Methodology, Writing — original draft, Writing — review and editing. D.S.: Data curation. L.E.: Data curation. A.B.: Data curation. D.L.C.: Data curation. R.M.S.S.: Data curation. F.B.: Conceptualization, Data curation, Methodology. F.A.S.M.: Conceptualization, Data curation, Methodology. S.A.M.: Conceptualization, Formal analysis, Writing — original draft, Writing – review and editing. W.F.A.: Data curation, Formal analysis, Writing — original draft, Writing — review and editing. A.A.J.: Data curation, Formal analysis, Writing — original draft, Writing — review and editing. M.D.M.: Conceptualization, Formal analysis, Methodology, Project administration, Supervision, Visualization, Writing — original draft, Writing — review and editing.

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