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Authors: Ghizela Ana Maria Salagean, Zoltan Balint, Philip Poortmans, Daniel Portik

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Can the daily position of bolus material influence radiotherapy treatment?

Ghizela A-M Salagean[1, 2], Zoltán Bálint[1], Philip Poortmans[3, 4], Daniel Portik[2, 5]

[1]Faculty of Physics, Babes Bolyai University Cluj-Napoca, Romania

[2]TopMed Medical Centre, Targu Mures, Romania

[3]Department of Radiation Oncology, Iridium Netwerk, Antwerp, Belgium

[4]Faculty of Medicine and Health Sciences, University of Antwerp, Belgium

[5]European Organisation for Research and Treatment of Cancer (EORTC) Headquarters, Brussels, Belgium

Corresponding Author: Ghizela A-M Salagean, Babes Bolyai University, Kogalniceanu 1–3, Cluj Napoca, Romania, tel: +40 729 046 297; e-mail: anamaria.salagean.21@gmail.com, ghizela.salagean@ubbcluj.ro

Abstract

Background: Daily bolus positioning implies a high degree of variability, which can affect the dose distribution within the planning target volume (PTV) and the organs at risk (OAR). We carried out a retrospective study to evaluate bolus positioning in patients with breast cancer.

Materials and methods: We evaluated 7 cases with left and 5 cases with right chest-wall with comprehensive nodal region irradiation in which bolus material was used to obtain better skin surface coverage. The bolus positioning on the daily cone-beam computed tomography images was compared to the reference image from the treatment planning system. Deviations from the reference position of the bolus were categorized as positive shifts (PosS) or negative shifts (NegS), depending on the material's overlapping with its planned position. Subsequently, a second plan was calculated using the information from the CBCT images for comparison with the original treatment plan. We performed a statistical and dosimetric analysis on the results.

Results: For both the 95% dose coverage for the PTV for the chest wall and for the lymph node regions, about 2% variation between initial and recalculated plans was seen, with a shift of the hotspots' position in some cases. The average mean heart dose was 4.1 ± 0.3 Gy, whereas the values for PosS and NegS mean heart doses were 3.8 ± 0.4 Gy and 4.0 ± 0.6 Gy, respectively. In contrast to the original values for the ipsilateral lung V5 (57.1 ± 12.9%), V20 (30.2 ± 2.7%), and Dmean (15.0 ± 1.7 Gy), the values for PosS were 56.1 ± 4.2% for V5:, 30.1 ± 3.3% for V20, and 14.9 ± 1.2 Gy for Dmean while for NegS we obtained 56.9 ± 8.9% for V5, 30.0 ± 2.3% for V20, and 15.2 ± 1.8 Gy for Dmean.

Conclusion: We observed dosimetric differences between the initial and given treatment plans depending on the position of the bolus for all cases, indifferent of the shift direction. Although the differences were not statistically significant, we identified a few specific instances where the variations might cause uncertainties regarding doses to the OAR. We suggest therefore that strategies for correct daily reproducibility of the bolus need to be implemented on a departmental level.

Keywords: bolus material; breast cancer; positioning; radiotherapy

Introduction

Breast cancer is the most prevalent cancer globally, with an age-standardized incidence rate of 46.8 in women and 0.61 in men [1–4]. Radiation therapy (RT) plays a critical role in the multidisciplinary management of breast cancer, particularly in the postoperative care of both lumpectomy and mastectomy patients [5–7].

An important challenge in chest wall radiation with photon radiation is to achieve adequate dose coverage on the skin surface area in certain circumstances where there exists a higher chance of superficial recurrences [8]. During radiation therapy additional steps are required, e.g., the application of tissue equivalent material, like bolus material on the skin surface to maximize or to add radiation dose to an irradiated area [9]. Such bolus materials include tissue-equivalent materials like rubber, wax, or water-equivalent gels [10]. The clinical use of commercial bolus material in RT has been extensively studied and compared to its alternatives. Several articles have explored the efficacy and dosimetric impact of different bolus materials, aiming to evaluate the benefits and drawbacks of various commercial bolus materials to optimize radiation treatment outcomes [11][12]. The use of bolus material is only recommended in specific clinical

settings of postmastectomy RT, according to a recent international consensus led by Kaidar-Person et al. [13]. Nonetheless, its use is a source of positioning error, potentially hindering reproducibility. In a review of the literature, the reproducibility of the bolus seems to be considered as a simple task, without raising the question of the daily positioning variation [14]. We wish to draw attention to the finding that there is currently no bolus positioning guideline published, to our knowledge by any of the major RT societies, for centres to follow. This stands in contrast for example with the head & neck immobilization mask guideline published by Michelle Leech in TipsRO [15]. Therefore, our question was to evaluate the dosimetric impact of the bolus positioning in a pilot study." We aimed to analyse the potential modifications of the dose distribution to the planned target volume (PTV) due to the bolus positioning differences in postmastectomy breast cancer patients. We made a retrospective comparison between the treated and recalculated dosimetric plans, where we analysed the variability of the bolus material position and the dosimetric changes in PTV coverage and the organs-at-risk dose (OAR).

Materials and methods

Patient selection

For this retrospective study, 12 total postmastectomy breast cancer cases with non-skin sparring approach were selected from our institutional database treated between March 2021 and May 2023, where a 0.5 cm thick Klarity Superflab bolus material was used to obtain better skin surface coverage (Radiation Products Design, Inc). All clinical target volumes (CTV) were defined according to the ESTRO guidelines [14]. For all cases, postoperative radiation therapy was given at a dose of 50 Gy in 25 fractions, to the chest wall (PTV CW) ± nodal regions [internal mammary (PTV IMN), axillary, and supraclavicular nodes (PTV_N)]. Nine of the 12 patients were treated with intensity-modulated radiotherapy (IMRT) and 3 with volumetric modulated radiotherapy (VMAT) technique. The treatment plan was split into two parts, the first 13 fractions treated with bolus, and the last 12 fractions without bolus material, to avoid excessive skin adverse events. All patients were treated with one daily fraction for 5 days per week for 5 weeks. According to the exclusion criteria, 4 out of the 12 selected cases were ineligible for analysis because of bilateral radiation therapy, major shifts, change of bolus used at mid-treatment, or irreproducible positioning due to chest wall anatomy (Fig. 1A).

In all evaluated cases, the patients were scanned in the supine position, and a standard breast immobilization device was used on the computed tomography (CT) table for positioning. The treatment position for each patient was with both arms above the head. The CT images were acquired using a CT–Simulator (Siemens Somatom Emotion, Siemens Healthineers), where the slice thickness was set to 5 mm to include all regions of interest. All patients were scanned with the free-breathing technique, without bolus material. The treatment planning system (TPS) Monaco 6.1 (Elekta™, Stockholm, Sweden) was used for contouring and treatment planning. The planning target volume (PTV) was obtained by using three-dimensional (3D) automatic expansions of CTVs, adding 7 mm in all directions (as per local institutional guidelines), and a 0 mm margin crop in the anterior (A) direction from the skin surface. A virtual bolus was created in the TPS and used in the calculations. The dimension of the virtual bolus was identical to the one used during the treatment with a thickness of 0.5 cm and a surface coverage of 30 x 30 cm.

Dosimetric comparison and statistical analyses

We evaluated the cone-beam computed tomography images (CBCT) of all 8 patients. The kV-CBCT images were acquired for each patient during every single fraction using the Elekta Medical Systems linear accelerator equipped with kV imaging capabilities (Elekta™, Stockholm, Sweden). The acquisition parameters were as follows: kVp, 120 kV; nominal scale dose (A1-2-44), 3.8 mGy; 330 frames, kV filter, f1; and CC gantry rotation, −180°–180°. In our study, after fusing the images, we compared the cone-beam computed tomography (kV-CBCT) images with the reference image used during the planning process. The bolus shift from the planned position was measured with the Mosaiq 6.1 software ruler, provided by Elekta, by two independent reviewers (1 medical physicist and 1 physician), and the average value was extracted.

All datasets were manually analysed and in the prior statistical analysis outliers were eliminated using a local outlier factor, with a contamination threshold of 10% and Euclidian metrics. Depending on the orientation of the bolus shift we considered three directions: x = left-right, y = craniocaudal, and z = antero-posterior shifts. Each direction was divided into positive and negative movements. We considered a shift to be positive (PosS) if the bolus during the treatment overlapped the contoured bolus and crossed the exterior margins of the bolus volume, whereas shifts (NegS) were defined as negative when the bolus from the CBCT covered a smaller region of the chest wall than in the reference image.

After data selection and processing, a ‘median bolus displacement’ (MBS) from the bolus position variations was created (Fig. 1B).

Treatment plans were recalculated with the MBS. For plan calculation we used Monaco 6.1 TPS, and we kept the same format of the approved treatment plan, avoiding re-optimization of the plans. In cases where during the treatment we had positive and negative shifts of the bolus as well, we created two ‘median boluses’ and we analysed the weight for each plan separately. The plan comparison was made using the TPS-generated Dose-Volume histogram (DVH). For each patient we used the recalculated plan to assess the dosimetric parameters influenced by MBS. In this case, we had two approaches, the first one when the bolus material had positive displacement, and the second one where a negative shift was present.

The statistical analysis was performed with GraphPad Prism (v9.0, Graphpad Software, La Jolla, CA, USA). The differences between the planned position of the bolus and the calculated one were determined by using hypothesis testing. The distribution of all variables (PTV, PTV N, OARs constraints) was tested for normality using the D'Agostino-Pearson test. For the variables with Gaussian distribution, the differences between the planned position of the bolus and the calculated one were determined using a paired Student's t-test. For the variables with non-Gaussian distribution, we used Wilcoxon matched pairs signed rank test. For all the tests a p-value < 0.05 was considered significant.

Results

We could observe a dosimetric difference between the plans, both at the level of OARs and at the PTV level. The coverage of PTV95%-PTV doses was not compromised and the D95%>95% was respected (Tab. 1). However, we noticed a difference of ±2% between the initial and recalculated plans for both D95% for PTV CW and for PTV-N

However, in some cases we observed a modification of the dose distribution of D95%-PTV-N and the hotspots’ position (Tab. 2).

The PTV coverage was affected in PTV N, although the bolus shift in craniocaudal direction was not statistically significant ($p = 0.24$). Its value decreased from a 98.0 ± 1.5% (49 ± 0.75 Gy) to 96.6 ± 1.6% (48.3 ± 1.52Gy) with PosS and it increased to 98.3 ± 1.2% (49.15 ± 0.6 Gy) with NegS.

While we could not observe statistically significant differences for the dose to the OARs, we could highlight some individual cases where the differences could raise some concerns from a clinical point of view. For mean heart dose, we obtained an average of 4.1±0.3Gy, as compared to 3.5 ± 0.4Gy for PosS and 4.1 ± 0.6Gy in the case of NegS. Results of ipsilateral lung dose metrics were consistent across the measured lung constraints for treated plans, PosS and NegS. The V5 were 57.1 ± 12.9% for the treated plan, 56.1 ± 4.2% for the PosS plan, and 56.9 ± 8.9% for the NegS plan. Values for V20 were 30.2 ± 2.7%, 30.1 ± 3.3% in the PosS plan and 30.0 ± 2.3% in the NegS plan. Finally, for Dmean we noted 15.0 ± 1.7Gy in the treated plan, 14.9 ± 1.2 Gy in the PosS plan, while in the NegS plan we obtained 15.2 ± 1.8 Gy.

In case of negative shift of the bolus the doses at organs-at-risk were higher as compared to the planned ones in the TPS (Fig. 2). While in case of the positive shift, we could observe an improvement of the doses for OARs, but with a dose decrease at the level of the target volume.

Discussion

We identified 12 breast cancer patients who had radiation therapy treatment with bolus material at our clinic in an interval of 26 months. However, 1/3 of them were excluded from our study due to various reasons causing poor adherence to bolus best practice recommendations.

During the in-depth analysis of the results, we observed the following: 1) an irregular body surface was a confounding factor for incorrect bolus positioning and 2) the air gaps influenced dose distribution, 3) incorrect bolus size selection, in case of patients with high BMI value and 4) lack of specific internal RTT protocol. Given the larger aperture of the entering field in the VMAT approach, when compared to the IMRT technique, we can detect a greater influence of the bolus variability when considering the irradiation technique.

Considering the target volume coverage, in a positive bolus shift case the coverage was lower than the planned one because the irradiation fields were calculated for a certain depth initially. Also, we noticed a modification of the Dmax point localization, its position being directly influenced by dose distribution in the target volume, which depends on the penetrated tissue depth. Even while there was no statistically significant difference, our analysis of the dose constraints highlighted several changes that could have an impact on the frequency and severity of side effects.

Our study has several limitations. The fractionation schedule is non-standard according to current best practices [16], but the outcomes will be identical for a contemporary fractionation schedule such as 40 Gy in 15 fractions over 3 weeks. Four out of the 12 patients were not eligible for our study; however, we anticipate that our findings are likely to be even more important for patients with less uniform anatomy. The slice thickness of 5 mm used for the CT-simulation was standard for our institution at the time of the study. Our bolus protocol, 13 fractions on and 12 fractions off, does not conform to the international consensus because of radiobiological considerations. However, this will not impact on the findings of our study as those are based on a mean of 25 fractions, so identical to using daily a bolus of half-thickness. However, depending on the bolus material, the reproducibility of positioning might be superior for a thinner bolus, which could decrease the impact of our findings.

Nevertheless, our study shows that daily bolus reproducibility has implications for the doses delivered to PTV and OARs. The first step in detecting these mistakes was to convene a joint committee of physicians, physicists, and technicians to identify the best way to avoid the mistakes made by each party. As a result, the RT team suggests classification of patients and their identification according to needs with thorough analysis of the patient whether they are a candidate for the use of bolus. Physicists implemented the following changes: standard 30 × 30 cm boluses were used in all cases where a bolus is needed, and its position is marked by coordination so that it can be positioned at the same points on the surface of the patient's chest wall (Figure 3). Another intervention for improvement was to scan the patient with a bolus when the surface of the skin is not uniform, and a superflab or a moldable bolus material cannot be used. **At the moment of this retrospective study,**

Conclusion

In conclusion, the present study underlines the significance of considering the position of the bolus material during daily RT fractions. We have demonstrated that the variation in bolus position can result in substantial differences between the estimated dose distribution and the actual dose delivered to the target area. These findings highlight the importance of accurate bolus placement and emphasize the need for regular assessment and adjustment during all RT procedures. By minimizing discrepancies between estimated and delivered dose distributions, healthcare professionals can enhance treatment effectiveness and improve patient outcomes.

Further research and technological advancements are warranted to develop more precise techniques for bolus positioning, ensuring optimal radiation dose delivery and maximizing the benefits of this therapeutic modality.

Conflict of interest

Authors declare no conflict of interest.

Funding

None declared.

Data availability statement

Research data are stored in an institutional repository and will be shared upon request to the corresponding author

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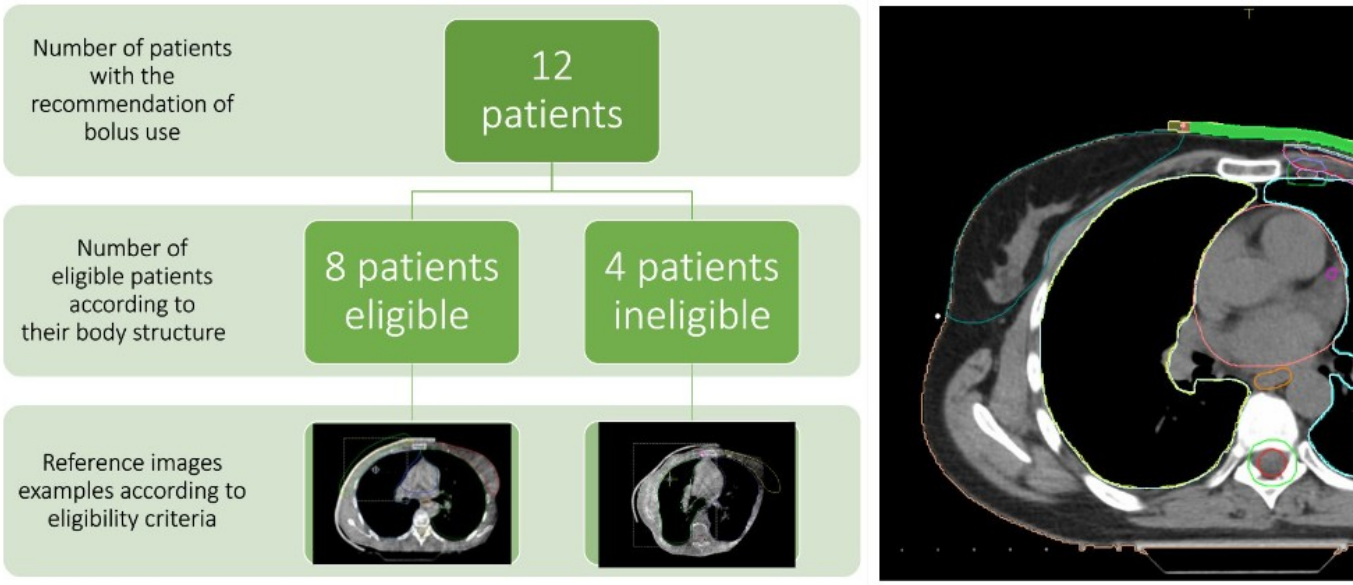

Figure 1.A. Patient distribution according to eligibility criteria; **B.** Comparison between positive shifts (PosS; yellow), negative shifts (NegS; green) and planned bolus (magenta) size for a representative case (PTV-red)

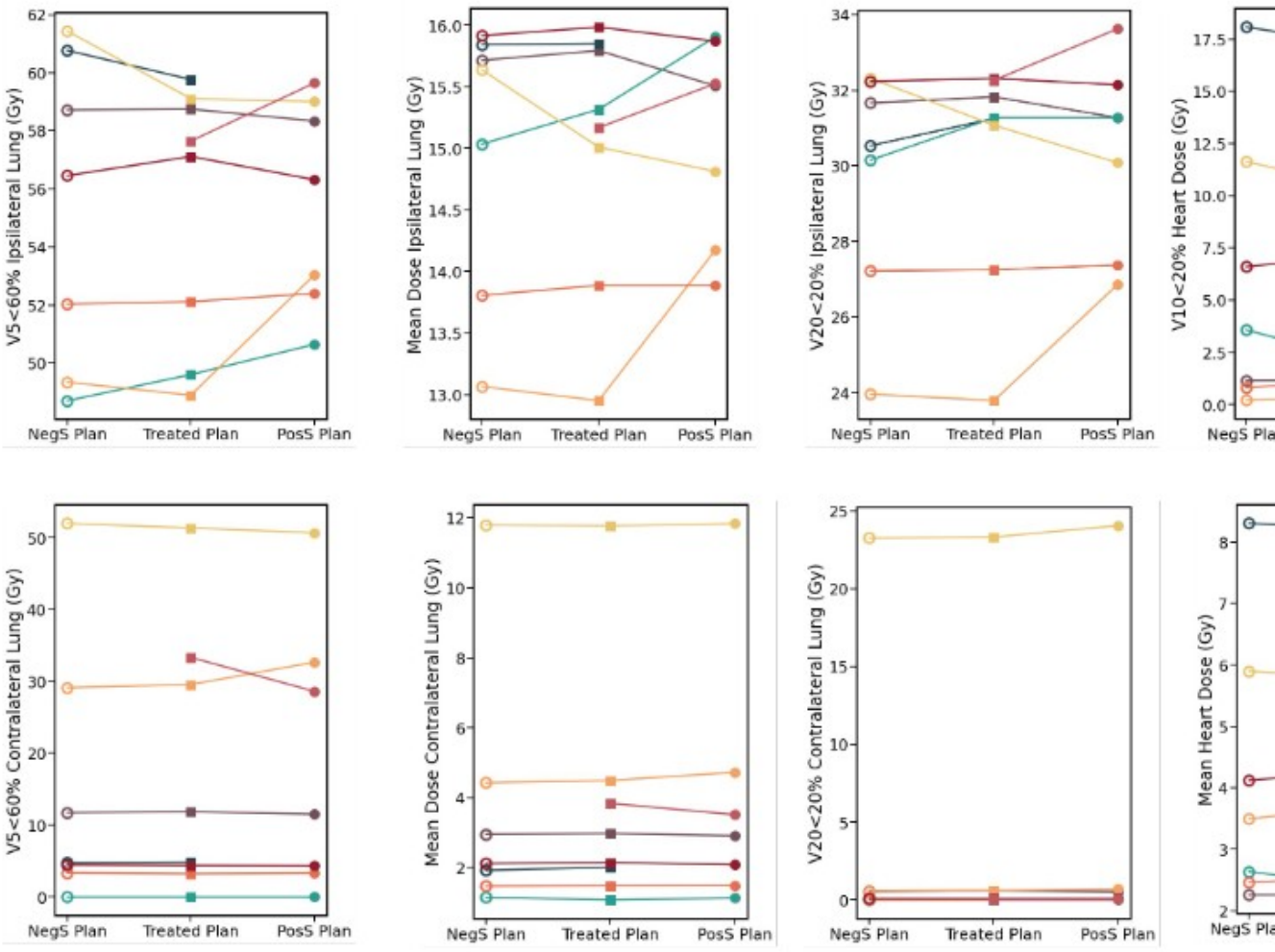

Figure 2. Dose deviation for organs at risk (OARs) in treated plans compared to negative shifts (NegS) and positive shifts (PosS plans) (each colour represents a different patient)

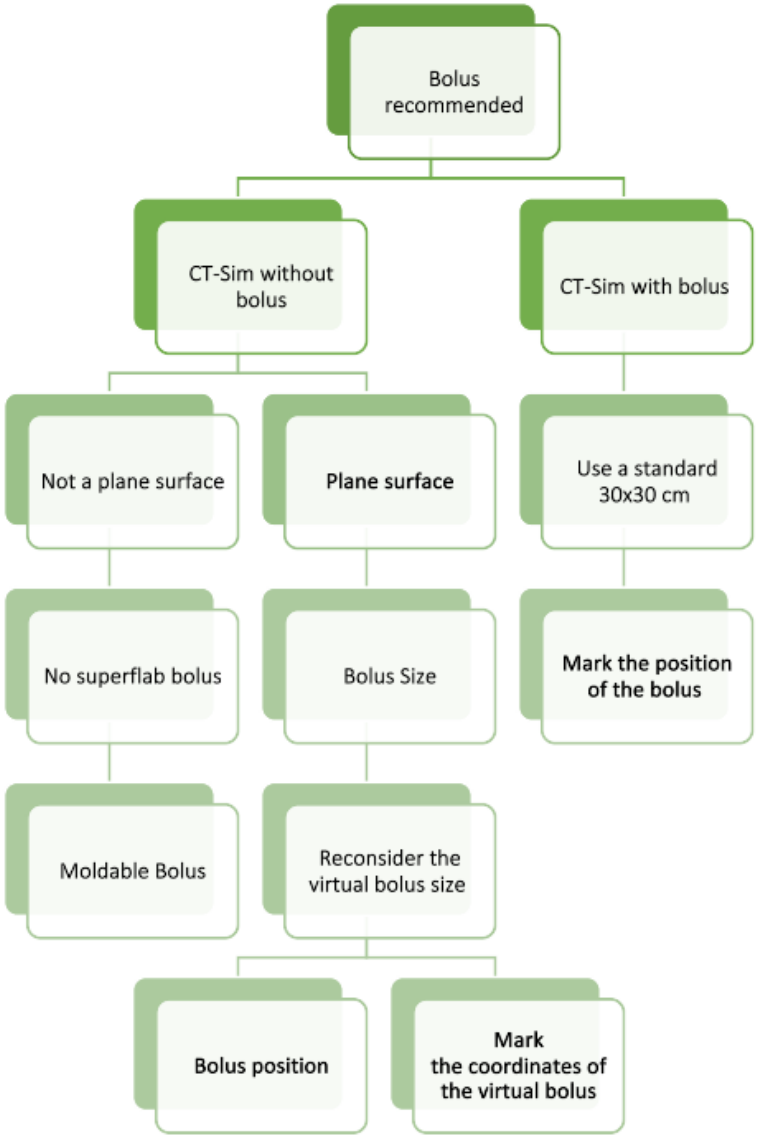

Figure 3. Bolus selection procedure and steps to follow

Table 1. Planning target volume (PTV) coverages for CHEST WALL with: treatment plan and recalculated (R) positive shifts (PoS) and negative shifts (NegS) plans

PTV V95%	**R plan for NegS**	**Treatment plan**	**R plan for PosS**
P1	97.22	97.93	95.44
P2	95.59	95.9	N/A
P3	95.85	95.83	95.7

P4	97.39	97.42	96.92
P5	99.84	99.8	99.81
P6	98.78	98.77	98.47
P7	94.92	95.37	93.69
P8	N/A	96.61	97

N/A — not available

Table 2. Planning target volume (PTV) Dmax points for treatment, negative shifts (NegS) and positive shifts (PosS) plans

	Dmax position			**Dmax %**			**PTV N 95%**		
	R plan for NegS	Treatment plan	**R plan for PosS**	**R plan for NegS**	**Treatment plan**	**R plan for PosS**	**R plan for NegS**	**Treatment plan**	**R plan for PosS**
P1	PTV IMN	PTV N	PTV IMN	105.48	105.56	105.76	97.8	98.09	95.66
P2	PTV PT	PTV N	N/A	109.26	107.13	N/A	98.53	98.87	N/A
P3	PTV PT	PTV PT (CIE)	PTV PT	107.91	107.06	108.16	97.13	97.25	98.18
P4	PTV PT	PTV IMN	PTV IMN	104.61	104.61	104.61	97.93	97.89	98.39
P5	PTV N	PTV PT	PTV N	105.9	105.79	106.56	99.53	99.6	99.65
P6	PTV IMN	PTV IMN	PTV IMN	107.26	106.6	106.6	99.41	99.07	99.45
P7	PTV N	PTV N	PTV N	104.95	105.21	104.65	98.08	97.78	97.55
P8	N/A	PTV IMN	OUT of PTV	N/A	106.8	106.41	N/A	96.03	97.29