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Effect of Bolus Frequency and Its Thickness in Postmastectomy Three-dimensional Conformal Radiotherapy on Skin Dose for Superposition Algorithm

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ABSTRACT

Introduction: The postmastectomy radiotherapy uses bolus to improve the coverage close to the skin; however, it needs to be removed in case of severe skin toxicity. This study investigated the effect of bolus parameters (i.e., frequency and thickness) for the superposition algorithm on skin dose in postmastectomy three-dimensional conformal radiotherapy (3D-CRT).

Material and Methods: The present study was carried out on a total of 22 patients. First, all the plans were calculated without using bolus. Then, the plans were recalculated using different bolus frequencies (5, 10, 15, 20, 25) and thicknesses (0.5 and 1 cm). To evaluate the dose delivered to the skin, a 2-mm thick skin was profiled, and statistical analysis was performed by studying the dosimetric parameters (i.e., minimum, mean, and maximum) of chest wall skin.

Results: The superficial coverage of planning target volume (PTV) was better by using bolus. In the case of skin, the bolus thickness had a significant impact on the minimum and mean doses for all bolus frequencies ($p \leq 0.05$), while there was no significant effect on the maximum before 20-bolus frequency. The bolus frequency increase demonstrated a significant difference on all dosimetric parameters of the skin ($p \leq 0.05$), except the maximum showed no significant difference between 0 and 5-bolus frequencies (p>0.05).

Conclusion: The obtained results indicated that the bolus use had generally a significant effect on the chest wall skin dosimetric parameters depending on bolus frequency and thickness. Therefore, the choice of bolus frequency and bolus thickness can affect the clinical decisions in certain cases.

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Introduction

Postmastectomy radiotherapy is delivered to the chest wall and sensitive nodal sites to reduce recurrence and get rid of any residual cancer cells of patients with locally advanced breast cancer [1]. In fact, the high-risk area of recurrence includes the entire soft tissue of the chest wall comprising residual breast tissue, connective tissue and the regional lymphatics [2].

Chest wall irradiation after mastectomy can be very complex due to many factors, including the irregular surface contour, large curvature and superficial part of target volumes requiring bolus use [3].

Furthermore, the bolus can be used either for the whole treatment or a partial treatment course [3]. The bolus is a tissue-like material frequently placed on the skin in order to minimize the skin-sparing effects of high-energy photons and enhance the coverage of the superficial part of the planning tumor volume (PTV). However, an international survey of radiation oncologists published in 2006 [4] highlights the variability in practice.

This study showed that bolus use is a compromise between the team members that consisted of physicians and physicists responsible for the treatment. In addition, the American Society of Clinical Oncology has also provided guidelines for postmastectomy radiotherapy in 2001 [5]; however, similarly, no advice has been given on bolus use.

Based on the evidence, the use of bolus for patients with irradiation-induced dermatitis can be accompanied by a range of complications from moist desquamation to ulceration or even necrosis. This can cause significant pain and immediate interruption of treatment, which may be prejudicial to local control [6]. The skin is the largest organ in the human body; in fact, it has an extremely complex structure with auto-repair when irradiated. Depending on the location, the

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skin has an average thickness of 2-3 mm in healthy adults [7].

The present study was limited to the superposition algorithm implemented in CMS XiO software (version 5.0.0) that is a widely used treatment planning system available for clinical dosimetry. The superposition algorithm takes on more fundamental physics theory to calculate dose deposition in a patient. The dose computation is based on the convolution of the total energy released per unit mass with precalculated kernels by Monte Carlo [8]. In addition, to take tissue inhomogeneities into account, previous papers have been investigated the density scaling method used in the superposition algorithm [9,10], which is based on O'Connor's scaling theorem [11].

Various irradiation techniques have been used to treat the delineated volumes after mastectomy. The techniques using a single isocenter or two isocenters have been described by Horst et al. [12]. With each method, it is important to pay attention to the beam arrangements, use of bolus and beam modifiers in order to optimize the dose distribution and abide by the recommendations of the International Commission on Radiation Units and Measurements (ICRU50) (95%-107%) [13].

Materials and Methods

Patient selection and target definition

The present study was carried out on 22 patients with breast cancer who underwent mastectomy followed by adjuvant radiotherapy to the chest wall and nodal sites. For each subject, the data of computed tomography (CT) scan were acquired using General Electrical Medical Systems (OPTIMA CT 580) with slice thickness of 3.75-5 mm. The CT scan data were transferred to a treatment planning system. Afterward, the chest wall and draining lymphatics (when clinically indicated) target volumes were delineated according to consensus definitions reported in Radiation Therapy Oncology Group (RTOG) Breast Cancer Contouring Atlas [14].

The target volumes included the chest wall clinical target volume (CTV), the axillary level III and supraclavicular lymph nodes were outlined. The delineated organs at risk (OARs) were the heart, ipsilateral lung, whole lung, contralateral breast and spinal cord. A radiation oncologist approved all contours of the target volumes and OARs. The PTV was defined by adding 5-mm margin isotropically to CTV and the superficial PTV contour was subsequently outlined 3 mm under skin surface [15,16] because the blood vessels of the skin pass in the first 5 mm below the epidermis [17]. In addition, to accurately assess skin dose, a volume, including 2-mm surface thickness, was contoured as skin structure.

Treatment planning

This study included 22 treatment plans developed in the superposition algorithm of CMS XiO software (version 5.0.0) to treat chest wall and draining lymph nodes. The prescription dose was 50 Gy in 2 Gy per fraction for target volumes, and static photon beams of 6 MV (in some cases mixed with 10 MV or 18 MV) were utilized for planning treatment.

For each patient, treatment plans were performed using mono-isocentric technique. Figure 1(a) displays the planning procedure that was initiated by placing the isocenter at the inferior edge of the clavicular head, and then all the fields were set by this isocenter. Figure 1(b) depicts two tangential fields that were used to treat the chest wall without using bolus, and an anterior oblique field was utilized to cover supraclavicular and the axillary level III targets. For the tangential fields, the superior half of the field was closed by superior collimator jaw (set to zero). However, the inferior half of the field was closed, when the anterior oblique field was set. The size of the tangential field may vary up to 20 cm to cover the chest wall.

The beam weights, wedge angles and field-in-field technique were chosen to improve dose uniformity of the target volumes. Multi leaf collimators were used to minimize the dose for the lung and heart. With this technique, no couch rotation is necessary and no divergence or overlapping occurs between tangential and anterior fields. Furthermore, all the fields can be treated in succession without moving the patient.

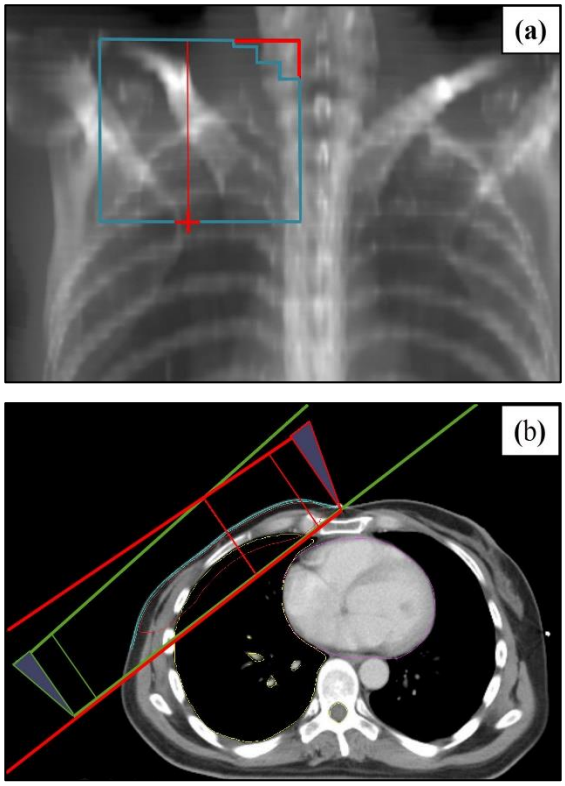


Figure 1. (a) Isocentric point and beam's eye view of anterior oblique field; (b) an example of two tangential fields (with wedge) encompassing the chest wall

All the treatment plans were evaluated based on isodoses (95%-107%) for the target volumes and cumulative dose-volume histograms (DVH) for organs

at risk. A radiation oncologist approved the treatment plan for each patient. To carry out the present study, copy plans of all original plans in superposition algorithms were realized. New plans were recalculated using bolus (i.e., Vaseline bolus with 1 g/cc density). For each bolus frequency (5, 10, 15, 20, 25) at 0.5 and 1 cm bolus thicknesses, the new plans kept the same parameters as the original ones. When the bolus frequency was 5, it meant that only 5 fractions were treated using bolus, and the remaining 20 fractions were treated without using bolus.

In order to analyze the treatment plans in the conformal radiotherapy, the homogeneity index (HI), conformity index (CI), and target coverage (TC) were calculated for PTV. The homogeneity index was defined according to RTOG definitions [18], the conformity index and target coverage were developed by Lomax et al. [19]. These variables are defined as follows:

$$HI = \frac{I_{max}}{RI} \quad (1)$$

$$CI = \frac{V_{PTV,RI}}{V_{RI}} \quad (2)$$

$$TC = \frac{V_{PTV,RI}}{V_{PTV}} \quad (3)$$

Where I_{max} is the maximum isodose in the PTV, RI is the reference isodose (95% of prescription dose, ICRU50), $V_{PTV,RI}$ is the volume within the PTV irradiated to at least the reference isodose, V_{RI} is the total volume in chest wall region enclosed by the reference isodose, and V_{PTV} is the volume of PTV structure.

The HI assesses the homogeneity of the dose distribution in the PTV. Moreover, its ideal value is 1 and increases as the plan becomes less homogeneous. In addition, a value less or equal to 2 is considered as RTOG protocol [18]. Afterward, the CI evaluates the conformity of reference isodose to the PTV, the CI equal to 1 corresponds to ideal conformation, and a value of 0.5 or higher would be comparable to the RTOG recommendation of a CI value between 1 and 2 [18]. Finally, the TC evaluates the coverage of the PTV by the reference isodose, and TC equal to 1 represents the perfect coverage.

Statistical analysis

The minimum, mean, and maximum skin doses were checked as a function of bolus frequencies at 0.5 and 1 cm bolus thicknesses. Each skin dosimetric parameter was analyzed for all patient plans. The Wilcoxon sign-rank test was utilized to compare the dosimetric change on skin dosimetric parameters regarding bolus frequency and thickness. P-value less than or equal to 0.05 was considered statistically significant to reject the null hypothesis.

Results

To improve the coverage of the superficial part of the planning tumor volume, the bolus of different thicknesses and frequencies was used on the chest wall. However, the achieved skin doses should be considered. Figure 2 shows the transversal dose distribution of shifting isodoses of 95% (green fill lines) and 107% (blue fill lines) for six studied frequencies at 1 cm bolus thickness, respectively, to illustrate the changes in the build-up region.

Figures 3 (a) and (b) show an example of DVH for 1 cm bolus thickness for the skin and PTV structures, respectively. In the case of the skin, the impact of the bolus frequency on DVH is very clear. The irradiated volume of skin was presented for different bolus frequencies and received the total prescribed dose beyond the frequency 20.

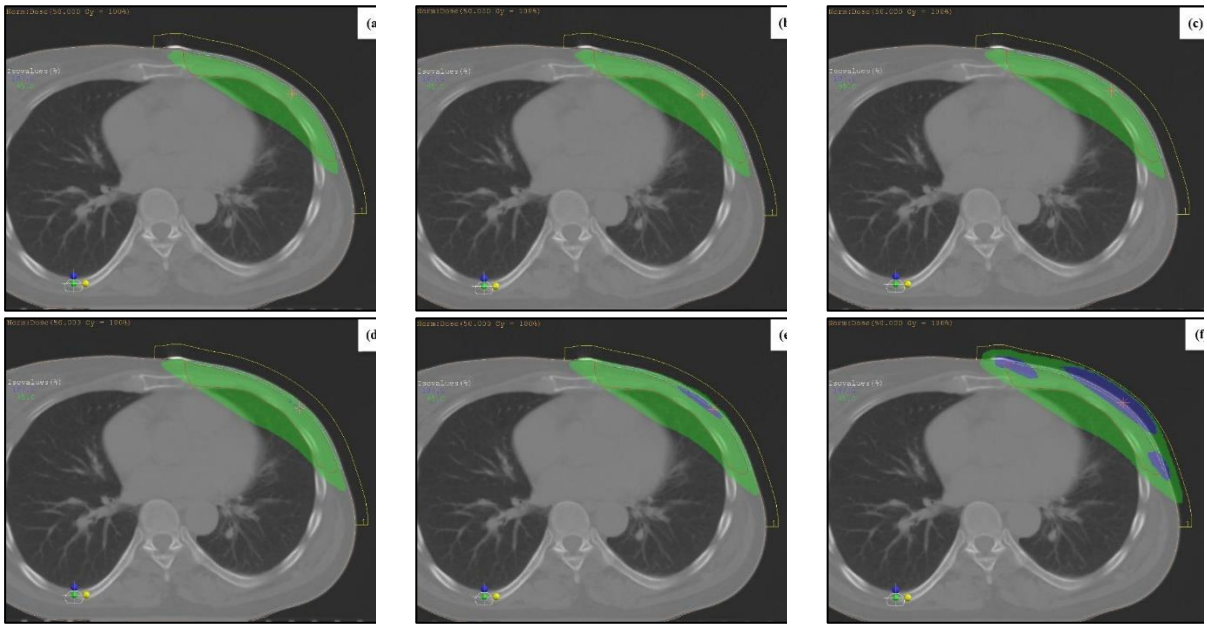


Figure 2. Transverse dose distribution curves at 1 cm bolus thickness; Subfigures (a, b, c, d, e, f) showing shifts of 95% (green) and 107% (blue) isodoses for 0, 5, 10, 15, 20, and 25 bolus frequencies, respectively

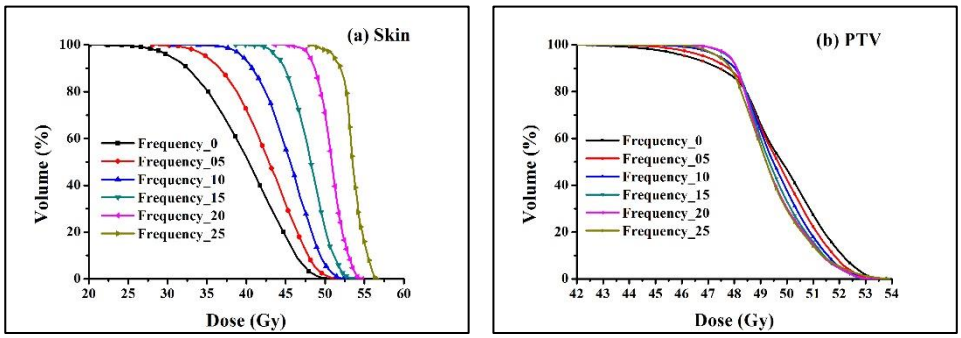


Figure 3. Dose-volume histograms of (a) skin and (b) planning target volume (PTV) structures according to six bolus frequencies for superposition algorithm(50 Gy=2 Gy×25), 6 MV photon, and 1-cm bolus thickness

Table 1. Summary of evaluated variables, including homogeneity index, conformity index, target coverage, and hot spots (Gy), for planning target volume of seven patients as function of bolus frequencies at both bolus thicknesses

Patients	Variables (0.5 vs.1 cm)	Frequency_0	Frequency_5	Frequency_10	Frequency_15	Frequency_20	Frequency_25
1	Homogeneity index	1.13 vs. 1.13	1.14 vs.1.14	1.15 vs. 1.15	1.15 vs. 1.16	1.16 vs. 1.18	1.17 vs. 1.19
	Conformity index	0.59 vs. 0.59	0.58 vs. 0.59	0.56 vs. 0.56	0.55 vs. 0.55	0.53 vs. 0.52	0.51 vs. 0.50
	Target coverage	0.92 vs. 0.92	0.93 vs. 0.93	0.94 vs. 0.94	0.94 vs. 0.95	0.95 vs. 0.96	0.95 vs. 0.96
	Hot spots	53.9 vs. 53.9	54.20 vs. 54.27	54.49 vs. 54.79	54.79 vs. 55.35	55.19 vs. 56.04	55.76 vs. 56.77
2	Homogeneity index	1.13 vs. 1.13	1.13 vs. 1.13	1.13 vs. 1.13	1.13 vs. 1.14	1.15 vs. 1.15	1.16 vs. 1.18
	Conformity index	0.66 vs. 0.66	0.63 vs. 0.63	0.60 vs. 0.60	0.57 vs. 0.56	0.53 vs. 0.52	0.51 vs. 0.50
	Target coverage	0.90 vs. 0.90	0.90 vs. 0.90	0.90 vs. 0.90	0.91 vs. 0.91	0.91 vs. 0.91	0.91 vs. 0.92
	Hot spots	53.73 vs. 53.73	53.76 vs. 53.57	53.81 vs. 53.83	53.87 vs. 54.21	54.45 vs. 54.65	55.1 vs. 55.91
3	Homogeneity index	1.14 vs.1.14	1.14 vs. 1.15	1.15 vs. 1.16	1.16 vs. 1.16	1.18 vs. 1.18	1.19 vs. 1.22
	Conformity index	0.62 vs. 0.62	0.60 vs. 0.59	0.58 vs. 0.57	0.55 vs. 0.54	0.52 vs. 0.51	0.51 vs. 0.50
	Target coverage	0.97 vs. 0.97	0.98 vs. 0.98	0.99 vs. 0.99	0.99 vs. 0.99	0.99 vs. 0.99	0.99 vs. 0.99
	Hot spots	53.97 vs. 53.97	54.3 vs. 54.41	54.73 vs. 54.95	55.2 vs. 55.2	55.85 vs. 56.2	56.75 vs. 57.92
4	Homogeneity index	1.15 vs. 1.15	1.16 vs. 1.16	1.16 vs. 1.15	1.16 vs.1.16	1.17 vs. 1.19	1.18 vs. 1.22
	Conformity index	0.91 vs. 0.91	0.88 vs. 0.86	0.86 vs. 0.81	0.84 vs. 0.75	0.79 vs. 0.68	0.72 vs. 0.65
	Target coverage	0.73 vs. 0.73	0.78 vs. 0.83	0.83 vs. 0.91	0.88 vs. 0.95	0.92 vs. 0.97	0.93 vs. 0.98
	Hot spots	54.72 vs. 54.72	54.87 vs. 54.99	55.03 vs. 54.54	55.19 vs. 55.24	55.42 vs. 56.55	56.02 vs. 57.82
5	Homogeneity index	1.13 vs. 1.13	1.12 vs. 1.12	1.12 vs. 1.12	1.12 vs. 1.13	1.12 vs. 1.14	1.12 vs. 1.16
	Conformity index	0.61 vs. 0.61	0.62 vs. 0.62	0.62 vs. 0.62	0.61 vs. 0.62	0.60 vs. 0.63	0.57 vs. 0.59
	Target coverage	0.93 vs.0.93	0.94 vs. 0.94	0.93 vs. 0.95	0.93 vs. 0.95	0.92 vs. 0.95	0.90 vs. 0.92
	Hot spots	53.58 vs. 53.58	53.15 vs. 53.28	53.06 vs. 53.22	53.04 vs. 53.49	53.15 vs. 53.98	53.36 vs. 55.12
6	Homogeneity index	1.12 vs. 1.12	1.12 vs. 1.13	1.13 vs.1.13	1.13 vs. 1.14	1.14 vs. 1.15	1.16 vs. 1.17
	Conformity index	0.47 vs. 0.47	0.46 vs. 0.45	0.44 vs. 0.43	0.42 vs. 0.41	0.40 vs. 0.38	0.38 vs. 0.37
	Target coverage	0.81 vs. 0.81	0.84 vs. 0.85	0.86 vs. 0.88	0.88 vs. 0.90	0.89 vs. 0.91	0.90 vs. 0.92
	Hot spots	53.28 vs. 53.28	53.43 vs. 53.53	53.58 vs. 53.82	53.74 vs. 54.21	54.19 vs. 54.69	54.9 vs. 55.60
7	Homogeneity index	1.12 vs. 1.12	1.15 vs. 1.14	1.15 vs. 1.15	1.16 vs. 1.16	1.17 vs. 1.17	1.18 vs. 1.19
	Conformity index	0.65 vs. 0.65	0.64 vs 0.64	0.63 vs 0.63	0.62 vs 0.62	0.59 vs. 0.57	0.57 vs. 0.55
	Target coverage	0.85 vs. 0.85	0.88 vs. 0.88	0.91 vs. 0.92	0.93 vs. 0.94	0.95 vs. 0.95	0.95 vs. 0.95
	Hot spots	53.43 vs. 53.43	54.45 vs. 54.33	54.67 vs. 54.57	55.00 vs. 54.96	55.35 vs. 55.49	55.94 vs. 56.63

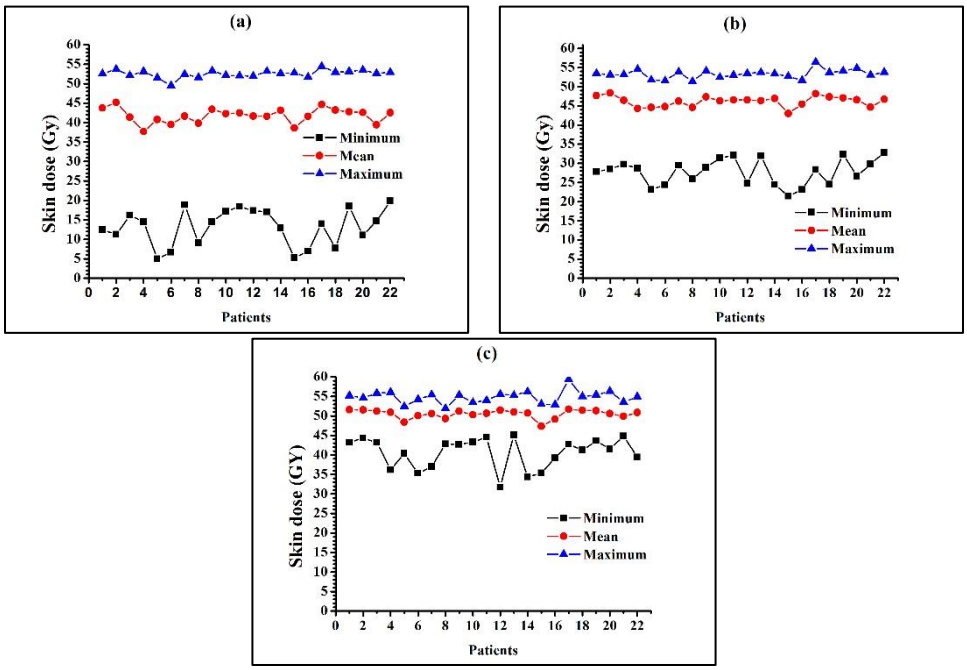


Figure 4. Dosimetric parameters of skin structure at 1 cm bolus thickness shown for all patients according to (a) bolus frequency_0, (b) bolus frequency_10, and (c) bolus frequency_20, respectively

Table 2. Dosimetric comparison of skin parameters between 0.5 and 1 cm bolus thicknesses for each bolus frequency

Bolus frequency	Minimum skin dose (Gy)			Mean skin dose (Gy)			Maximum skin dose (Gy)		
	0.5 cm	1 cm	P-value	0.5 cm	1 cm	P-value	0.5 cm	1 cm	P-value
0	11.99±4.35	11.99±4.35	1.000	42.18±1.93	42.18±1.93	1.000	53.01±0.71	53.01±0.71	1.000
5	18.80±3.85	19.75±3.89	0.005	44.06±1.74	44.28±1.75	0.005	53.24±0.97	53.33±0.96	0.092
10	25.25±3.77	27.05±3.70	0.005	45.93±1.58	46.36±1.60	0.005	53.67±1.18	53.81±1.29	0.059
15	31.57±3.96	34.20±3.62	0.005	47.79±1.45	48.44±1.48	0.005	54.15±1.44	54.43±1.67	0.059
20	37.61±4.30	41.00±3.68	0.005	49.66±1.36	50.52±1.39	0.005	54.76±1.73	55.43±1.99	0.017
25	42.60±4.61	45.83±3.58	0.005	51.22±1.32	52.60±1.34	0.005	55.68±1.85	57.21±2.35	0.007

For PTV volume, it appeared that the volume coverage reached 95% of the administered dose as the bolus frequency increases. On the other hand, due to deep areas of PTV, the volume coverage started to decrease when frequencies exceeded 20.

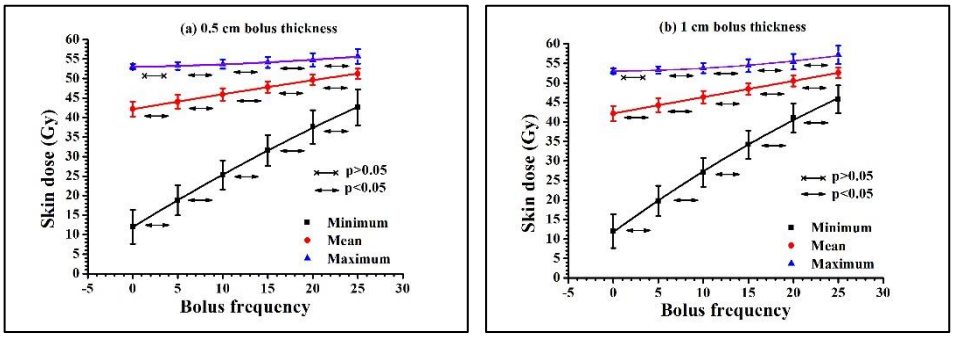
The combination of CI and TC allowed describing how well the PTV was treated for the reference isodose and how successfully the reference isodose avoided the normal tissue. A summary of variable values (i.e., HI, CI, TC, and hot spots) was constructed for a sample of patients that can be observed in Table 1. In general, the TC values increased with bolus frequency for both bolus thicknesses except in certain cases for high frequencies, which means that the volume covered by the reference isodose is usually better. Whereas, the CI values decreased for all patients indicating that the total volume enclosed by the reference isodose is always bigger than the PTV. Therefore, the normal tissue outside the PTV (especially skin) received more doses.

For each patient, the HI and hot spots (Maximum in PTV) were relatively constant or increased as a function of bolus frequencies at both bolus thicknesses. Additional optimization to reduce hot spots was required by the planner when applying the bolus. For all cases, the impact of bolus use on CI variable demonstrated the same behavior, as shown in Table 1. Therefore, it was required to study its impact on skin dose.

In order to illustrate the effect of bolus frequencies on skin dose, a comparison of various dosimetric parameters (i.e., minimum, mean, and maximum) with and without bolus were presented for all patients in Figure 4. Depending on the patient's anatomy and skin structure, a variation of dosimetric parameters was noticed with bolus frequency.

Table 3. Parameters of second-order polynomial fit function and adjusted R-square corresponding to dosimetric parameters of chest wall skin

	Bolus thickness	Intercept (Gy)	Coefficient B_1 (Gy)	Coefficient B_2 (Gy)	Adjusted R-Square
Minimum skin dose	0.5 cm	11.9142	1.4215	-0.0075	0.9997
	1 cm	11.7828	1.6774	-0.0122	0.9989
Mean skin dose	0.5 cm	42.1340	0.3974	-0.0013	0.9994
	1 cm	42.1846	0.4181	-0.0001	1.0000
Maximum skin dose	0.5 cm	53.0105	0.0337	0.0029	0.9981
	1 cm	53.0352	0.0164	0.0057	0.9872



(a) (b)

Figure 5. Impact of bolus frequency on minimum, mean, and maximum doses of skin at (a) 0.5 cm bolus thickness and (b) 1 cm bolus thickness.

Overall, a variation in the minimum and the mean doses of skin was observed when increasing the bolus frequency. However, no clear variation was noticed for the maximum skin dose. Therefore, to assess the effect of bolus thicknesses and frequencies on skin dose, statistical analysis was conducted for all the patients.

The average of skin dosimetric parameters with their standard deviations as a function of six frequencies at both bolus thicknesses was summarized in Table 2. In addition, P-values were reported to compare the impact of bolus thickness on dosimetric parameters of skin for each bolus frequency.

The bolus thickness has a significant impact on the minimum and mean doses of the chest wall skin for all bolus frequencies ($p < 0.05$), while there was no significant effect on the maximum before the 20-bolus frequency.

The relations between the dosimetric parameters of skin and its p-values as the function of bolus frequency for 0.5 and 1 cm bolus thicknesses are depicted in figures 5 (a) and (b), respectively. The fit functions to data points were plotted with solid curves for the studied parameters. Table 3 tabulates the intercept, coefficients B_1 and B_2 of the equations of the fit polynomials to data points with their adjusted R-square. The fit function is given by equation (4) as follows:

$$Y = intercept + B_1 * x^1 + B_2 * x^2 \quad (4)$$

Where Y is the dose corresponding to the studied parameters of skin and x is the bolus frequency.

These functions could be used to predict suitable bolus frequency when performing the dosimetry. Furthermore, the obtained results of the bolus application may encourage the treatment planner to use bolus, if acute skin toxicity and complications were avoided.

Discussion

The clinical utility of understanding the impact of bolus use seems to be evident. However, there is a wide variation in clinical bolus practice between clinicians around the world [4]. In addition, the bolus application requires recommendations such as applying it over the full chest wall or to the scar with margins, bolus thickness and days of bolus application, which could probably reduce acute and late skin toxicity and avoid treatment interruption.

The HI, CI, TC and hot spots are tools that can help to analyze the uniformity of dose distribution in the PTV. However, they could not replace the qualitative analysis of axial CT scan images of the plan. The TC indicated that the coverage using bolus was usually more acceptable with increasing bolus frequency at both bolus thicknesses. Accordingly, the results of Table 1 confirmed the relationship between no bolus and bolus use in the PTV.

As in the case of the target coverage, the CI represents another tool to quantify the volume exceeding the PTV and covering a part of OARs. Furthermore, the obtained results in Table 1 highlighted the impact of bolus frequency at both bolus thicknesses on chest wall skin during planning treatment by the CI decrease. The increase in hot spots was due to the impact of the bolus (frequency and thickness) on the build-up region, which

itself varied from one patient to another. Then, the HI increased slightly with the bolus frequencies at both thicknesses but can be considered protocol compliant.

Certainly, the superficial coverage of 1 cm bolus thickness was higher than that achieved with 0.5 cm bolus thickness for each bolus frequency. In addition, it was noted that the improvement of the chest wall coverage by varying bolus thickness had a significant impact on the minimum and mean doses of the skin for all frequencies. Consequently, the utilization of appropriate bolus thickness in treatment planning was a compromise to reduce substantially the uncertainty associated with the skin complication.

According to Table 2, while studying p-value for each bolus frequency between 0.5 and 1 cm bolus thicknesses, the impact of bolus thickness on skin dose should be considered for all frequencies for the minimum and mean parameters, while for the maximum, the impact was not significant until the frequency 20.

As presented in figures 5 (a) and (b), the dosimetric parameters of skin as a function of bolus frequencies showed a similar pattern at both bolus thicknesses.

For the minimum skin dose, the polynomial trend lines became more curved between 20 and 25 bolus frequencies that could be used to calculate the minimum skin dose for intermediary frequencies. A noticeable variation of the minimum dose occurred with increasing the bolus frequency($p \leq 0.05$). This finding was mainly due to the larger effect of the bolus in the build-up region.

By applying a bolus on the patient's surface, the electrons in the bolus material interact with the incident beam of photons, and then they will be moved forward to the patient's surface. As a result, the changes in percentage depth dose curve and its maximum dose move to reach the surface [20]. Furthermore, there are two sources of contamination one of which is the linac head components, such as the flattening filter, ion chambers, as well as primary and secondary collimators [21]. The other source is the treatment setup parameters (i.e., field size, beam modifiers, and focus-to-surface distance) [22], which was accurately modeled by the superposition algorithm.

For the mean skin doses, the dose variations as a function of bolus frequency were significant at both bolus thicknesses ($p \leq 0.05$). The mean dose of the skin increased almost linearly with bolus frequencies of 3.74±0.26 and 4.16±0.02 Gy at 0.5 and 1 cm bolus thicknesses, respectively. Finally, the maximum skin doses did not have a linear behavior, and polynomial lines of best fit were used to draw their curves. The difference was very small between frequencies 0 and 5($p > 0.05$). In general, the maximum dose of skin was represented by the hot spot, which can be shifted to another place and could probably be outside the body outline.

With regard to the performance of this study, it should be mentioned that the authors were not able to assign objective of acute toxicity grading or report late toxicity with the dosimetric parameters of the skin. However, the obtained results of this study suggested considering additional information in order to avoid more significant skin complications for the patients treated by bolus.

Conclusion

Although the superficial part of the PTV with photon beam using bolus is important in chest wall treatment. Furthermore, the influence of the bolus cannot be ignored on dosimetric parameters of chest wall skin. The application of bolus in the treatment plan will move the isodoses to surface that reduces the skin-sparing effect. This study highlighted the use of bolus technique for the chest wall cancer treatment.

The two studied parameters seem to be practical for chest wall radiotherapy. The dosimetric parameters of the skin obtained between 0.5 and 1 cm of bolus thickness were generally different for each bolus frequency. Furthermore, it may be observed that the variation of the minimum, mean and maximum skin doses were significant depending on bolus frequencies. Therefore, the choice of bolus frequency and bolus thickness should be considered while evaluating the treatment plans because it may clearly influence the clinical results.

The obtained results of the present study could not be generalized due to many factors, including the skin anatomy for each patient, calculation method using bolus, as well as different experimental groups and methods. However, the present study provided health practitioners with the treatment planning system, additional information that could influence the choice of bolus thickness, bolus frequency, and prescribed doses.

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