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DOSIMETRIC COMPARISON OF TANGENTIAL INTENSITY MODULATED RADIOTHERAPY (IMRT) PLANS WITH SKIN FLASH AND WITHOUT SKIN FLASH FOR BREAST CARCINOMA

Radiation Oncology

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ABSTRACT

Introduction: In the radiotherapy treatment of post-operative breast carcinoma, IMRT has become a common practice. IMRT has advantages in terms of better target coverage and organ at risk (OAR) protection as compared to 3-dimensional conformal radiotherapy (3DCRT). Due to breathing, the target volume extends beyond the contoured skin surface during treatment. The internal target movement may cause an underdose to the target surface. This study aims to explore dosimetric impacts of skin flash tool in IMRT plans for post- operative breast carcinoma. **Materials and Methods:** In this study, a total of twenty patients prescribed for post-operative radiotherapy in left breast carcinoma were chosen retrospectively. The prescription dose was 50 Gy in 25 fractions by the IMRT technique. Delineation of target and organ at risk (OAR) done as per RTOG guidelines. ICRU-83 recommendations were adapted for plan evaluation in each patient. Two IMRT plans were created: without skin flash (A) and with skin flash (B) of 10 mm thickness, respectively. To account for patient breathing movement, a 5 mm shift is applied vertically in B plans, and the data was taken as a new group (c) plans. The plans were created, maintaining beam energy, number of beams, beam angle and optimization objectives identical between plan A and B. Patient-specific quality assurance plans were created using the QUASAR body phantom, placing the Farmer chamber on the surface laterally. The mean dose of Farmer chamber sensitive volume is taken as the skin dose value in both the plans. For a statistical data analysis, a two-tailed paired student t-test was used. **Results:** All three group IMRT plans showed significant differences in PTV evaluation indices. In this measurement, the dose received by the skin is optimum in IMRT B than in the IMRT A plan. The dose received by OAR is significantly less in Group B plans than in Group I plans. **Conclusion:** This study suggests Skin Flash with 10 mm thickness will adequately account for a 5 mm breathing shift in the target. Institutions having limited advancement in treatmentmachines can adapt this method of planning for post-operative breast carcinoma, which will improve better plan quality execution.

KEYWORDS

INTRODUCTION

Breast cancer is the most frequently diagnosed malignancy and a leading cause of mortality among women. Modern multidisciplinary treatment strategies, encompassing surgical resection, postoperative radiation, and preoperative or postoperative systemic therapy, have significantly enhanced the long-term survival prospects of breast cancer patients. Notably, radiation therapy following breast-conserving surgery has exhibited outcomes on par with mastectomy, especially for early-stage cases; this has led to an increased emphasis on improving patients long-term quality of life while minimizing radiation-induced malignancy [1].

Breast cancer can be treated with radiotherapy using various methods, including conventional techniques, 3D Conformal Radiotherapy (3DCRT), and advanced state-of-the-art approaches. Compared with the traditional 3DCRT, IMRT had obvious superiority in the uniformity and conformal degree of the target volume, as well as the protection of organs at risk. However, the target volume of the chest wall extends beyond the skin due to the movement of organs such as breathing and heartbeat, which can potentially lead to underdosage of the target volume. So, by using the skin flash tool, we hope to achieve the radiation coverage of the target volume while minimizing the dose to the organ at risk (OAR) [2].

In the IMRT technique, "skin flash" prevents superficial tissue escape due to movement during treatment and contributes to a uniform dose distribution on the skin surface (the skin flash tool expands the fluidity beyond the body surface in the IMRT treatment of superficial tumors such as the head and neck, especially the breast). Skin flash is a function that prevents sudden dose changes in the beam field. In the literature, there are few publications on the application of skin flash of different thicknesses in the postoperative chest wall IMRT planning of breast cancer.

This study aims to dosimetrically compare the tangential IMRT plans with and without the skin flash tool in post-operative breast carcinoma.

MATERIALS & METHODS

Plan Creation:

Twenty patients with left breast carcinoma were selected retrospectively. And the Eclipse treatment planning system of version 17.0 is used to create the treatment plan. In each patient, three tangential Intensity Modulated Radiotherapy (IMRT) plans were created: Plan A iswithout the skin flash tool; plan B is with a 1 cm skin flash to account for anterior breathing movement [Fig. 1]; plan C is with a 1 cm skin flash + 5 mm anterior shift to account for setup error. 6 MV photon beam is used in all plans, keeping the number of beams and beam angle constant. In optimization, objectives of target volume and organ at risk (OAR) kept identical between three sets of plans in a patient. Normal Tissue Objective (NTO) values were chosen manually. Grid size used in optimization is 2.5 mm. Due to the machine's field size limitation; we were unable to perform optimization for the three breast patients. Analytical Anisotropic Algorithm (AAA) used for MU Calculation and evaluated by two methods. Quality assurance plans were created for all these plans and executed.

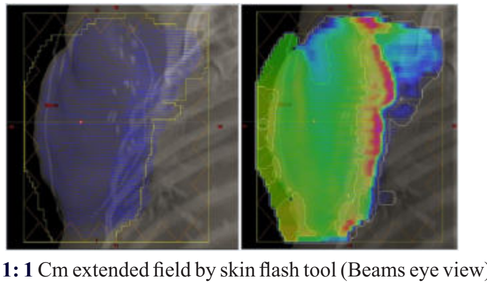

Figure 1: 1 Cm extended field by skin flash tool (Beams eye view) and Fluence extension of 1 cm by skin flash (Beams eye view)

Dosimetric Analysis: Target volume coverage is verified visually by checking isodose coverage in the transverse window, and the plan's statistical data were collected from the dose volume histogram (DVH). The coverage of the Planning Target Volume (PTV) was measured in this study by comparing the maximum, median, and minimum doses received by the PTV. The following OAR parameters were estimated from the DVH: PRV spine: D_{max}, Lungs: (D_{mean}), V_{20}, opposite breast: (D

10%), Heart: D_{mean}, V_{25}, V_{45}, and V_{50}. For statistical analysis, a two-tailed paired T-test is used.

Phantom Setup for Scan and Contouring:

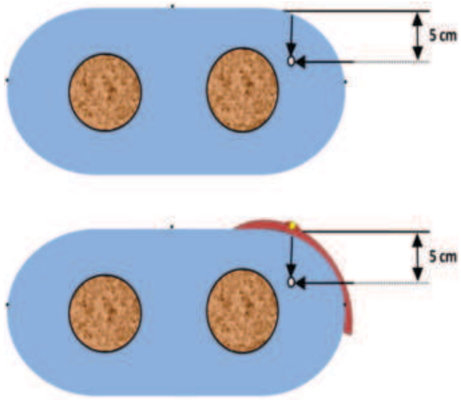

Figure 2: Iso centre placement and Chamber placement on thorax phantom

An ionization chamber is placed on the thorax phantom by using the adhesive material (paper was placed inside of the material to avoid contact with the sensitive volume of the chamber). With this placement we ensure that the chamber was not in contact with any material; to support the chamber, a piece of slab is placed. A 5mm thickness of wax bolus is placed laterally as a groove to the chamber. With this setup of the thorax phantom, we have scanned and contoured the chamber volume to know the skin dose.

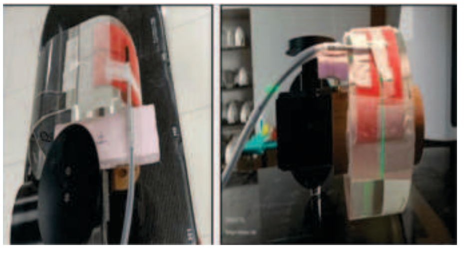

Figure 3: Anterior and lateral chamber position on thorax phantom surface.

Patient-Specific QA Plan Creation: The thorax phantom was scanned and uploaded in the Treatment Planning System. In the creation of patient-specific QA plans, the uploaded thorax phantom image is selected for the execution of those plans. Then those plans will be created in the Thorax image as a QA plan [Fig: 4].

Measurement setup on machine: All the QA plans of twenty patients are created, and the QA plan is executed by following the same setup while scanning the thorax phantom. The electrometer is connected to the chamber of +300 voltage, and temperature and pressure were noted. With this setup, QA plans were executed while the execution of the plan C, we have shifted the couch 5 mm vertically. The cumulative charge is noted for these plans, and then it was converted into Gy by using the calibration coefficient value and temperature and pressure correction factor value.

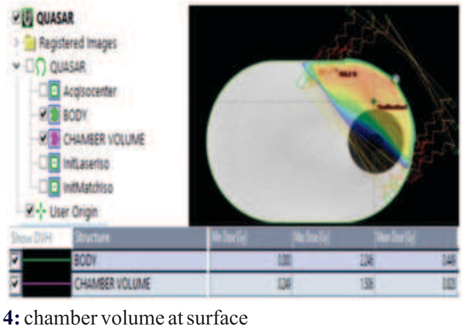

Figure 4: chamber volume at surface

RESULTS

The TPS dose and measured dose are closer in alignment compared to the first graph, suggesting that applying a skin flash improves dose prediction accuracy. However, discrepancies still remain for some patients, particularly in cases where the TPS dose is slightly lower than the measured dose [Fig. 5].

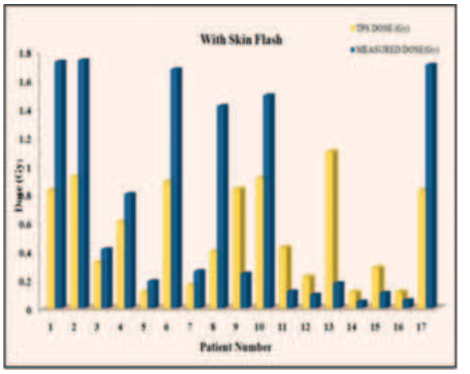

Figure 5: Comparison of TPS calculated dose and Measured dose with skin flash along the central axis

Introducing a -5 mm shift further improves the alignment between the TPS and measured doses.The differences are minimized for most patients, implying that shifting the skin flash region helps refine the TPS predictions to better match the measured dose [Fig. 6].

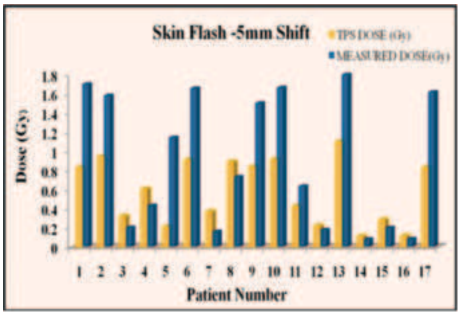

Figure 6: Skin flash with 5mm shift skin dose comparison

For most patients, the measured dose (blue bars) is consistently higher than the TPS dose (yellow bars).A significant discrepancy between the TPS dose and the measured dose isobserved, indicating the TPS underestimates the actual delivered dose in the absence of a skin flash [Fig. 7].

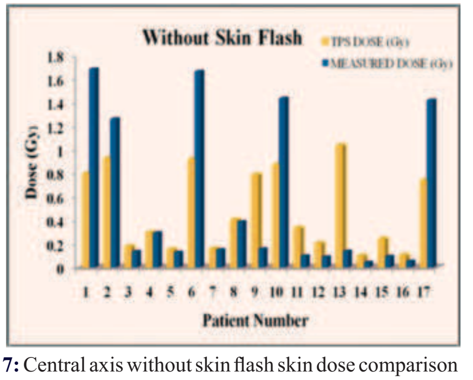

Figure 7: Central axis without skin flash skin dose comparison

PTV analysis shows a slight decrease in the conformity index (CI) with skin flash and a 5 mm shift (1.148 ± 0.105 to 1.21 ± 1.11), while the homogeneity index (HI) improves (0.304 ± 0.302 to 0.229 ± 0.142), indicating better dose uniformity with adjustments. [Table:1].

Table 1: CI and HI Comparison:

SKIN DOSE	Without Skin Flash (A) (Gy)	With Skin Flash (B) (Gy)	With Skin Flash + 5mm SHIFT (C) (Gy)
TPS Calculated dose	0.484±0.3444	0.515±0.348	0.583±0.337
Measured dose	0.542±0.624	0.661±0.689	0.926±0.728

This table reveals significant variations in dose distribution across OARs with skin flash and positional shifts. Lung Dmean and V20 significantly increased with a 5 mm shift (p = 0.000, p = 0.043), and heart V45 showed a notable rise (p = 0.001). PRV spine and opposite breast doses showed no significant differences. These findings emphasize the need for careful parameter optimization to minimize OAR exposure while maintaining treatment accuracy. [Table: 2].

Table 2: OAR Dose Comparison

PTV	WITHOUT SKIN FLASH (A) (Gy)	WITH SKIN FLASH (B) (Gy)	WITH SKIN FLASH + 5mm SHIFT (C) (Gy)
Conformity index(CI)	1.148 ±0.105	1.12±1.173	1.21±1.11
Homogenity index(H I)	0.304±0.302	0.284±0.313	0.229±0.142

Measured doses are consistently higher than TPS-calculated doses in all scenarios, according to skin dose analysis in Table 3. The addition of skin flash and a 5 mm shift significantly increases both calculated and measured doses, with the measured dose rising from 0.542 ± 0.624 (A) to 0.926 ± 0.728 (C), emphasizing the need for precise dose estimation in treatment planning.

Table 3: Skin Dose Comparison:

OAR'S	Without Skin Flash (A) (Gy)	With Skin Flash (B) (Gy)	With Skin Flash + 5mm SHIFT (C) (Gy)	P value (A & B) (Gy)	P value (B & C) (Gy)	P value (C & A) (Gy)
Lung D_{mean}	6.0757 ± 2.257	5.949 ± 2.636	7.069 ± 2.427	0.656	0.000	0.225
Lung V_{20}	12.23 ± 7.69	10.66 ± 3.515	13.94 ± 5.391	0.298	0.043	0.086
PRV Spine	1.01 ± 0.606	4.488 ± 10.245	1.103 ± 0.667	0.336	0.241	0.163
Opposite breast	8.041 ± 8.245	0.981 ± 0.6431	9.001 ± 7.411	0.146	0.262	0.542
Heart V_{25}	21.707 ± 12.506	21.74 ± 12.65	25.96 ± 13.67	0.867	0.358	0.351
Heart V_{45}	4.656 ± 5.655	5.001 ± 5.792	6.707 ± 6.902	0.177	0.001	0.001
Heart V_{50}	0.951 ± 1.779	0.629 ± 1.054	0.888 ± 1.523	0.226	0.151	0.838
Heart Dmean	13.16 ± 5.613	13.15 ± 5.788	14.89 ± 5.953	0.914	0.394	0.391

DISCUSSION

In radiotherapy for breast carcinoma, achieving optimal dose distribution while minimizing exposure to organs at risk (OARs) remains a critical challenge. The implementation of the skin flash tool in IMRT plans addresses the issue of target volume movement caused by breathing and heartbeat, which can lead to under dosing of the planning target volume (PTV). Our study demonstrated that the inclusion of a 10 mm skin flash significantly improved PTV coverage, with better conformity and homogeneity indices compared to plans without skin flash. Tang et al. conducted similar dosimetric study and concluded that although the skin dose was higher in the skin flash plan, OAR doses, including the heart and lungs, were consistently lower, showcasing its potential to enhance treatment precision and reduce recurrence risks. [3]

To mitigate underdoses on target surface , the skin flash tool was integrated into the IMRT plans to extend the fluence beyond the skin, ensuring adequate target coverage even during respiratory motion. Our dosimetric analysis compared plan-B and plan-A. The skin flash tool, revealing that the skin flash plan (B) provided superior coverage of the PTV, better conformity (CI), and improved homogeneity (HI) compared to the non-skin flash plan (A). Additionally, the dose to organs at risk (OARs) was reduced in plan (B), although the skin dose was higher than in plan (A).

Supporting our findings, Rakic et al. evaluated the effectiveness of a new fall-off (FO) margin technique, which similarly aimed to improve dosimetric outcomes by expanding the target volume beyond the skin. Their study highlighted that VMAT and IMRT plans achieved superior homogeneity and conformity indices compared to 3DCRT. Furthermore, they observed a significant correlation between physical breast dimensions and dose distribution, with the fall-off margin offering practical benefits in managing breast tissue motion during treatment. These results underscore the importance of tailoring radiotherapy techniques to individual patient anatomy to optimize therapeutic outcomes. In this study, a skin flash tool is used to extend the fluence to achieve homogeneity and conformity indices compared to without the skin flash tool. [4]

Additionally, Rang Tang et al. and Xiaoying Liang et al. demonstrated the dosimetric advantages of using skin flash and robust optimization methods, respectively, in IMRT plans. Both approaches effectively enhanced target coverage and minimized OAR doses, emphasizing the clinical applicability of advanced planning tools. [3][5]. Rang Tang et al., who developed IMRT-VB and IMRT-SF plans based on virtual bolus and skin flash tools, respectively. Their study concluded that the IMRT-SF plan demonstrated clinical advantages over the IMRT-VB plan, offering simpler operation and superior protection of OARs. Similarly, this study gives better homogeneity and conformity with a slight increase in skin dose and minimal dose to OARs. [3]

Jonathan Bogue et al. evaluated a skin flash method in volumetric modulated arc therapy (VMAT) for left breast cancer, showing that the technique delivered more homogeneous dose distributions and improved OAR sparing, at the cost of higher doses to some organs compared to 3D conformal techniques. Our results are consistent with these observations, confirming that skin flash improves target coverage and reduces OAR doses, although it may result in higher skin doses. [5]

Xiaoying Liang et al. explored different skin flash methods, including manual flash (MF), expanded PTV (Ex PTV), and robust-optimized (RO) plans, finding that the RO plan provided the best robustness against target position variation without compromising the dose to OARs. This is particularly relevant to our study, as our use of the skin flash tool aimed to enhance treatment robustness by compensating for respiratory motion while maintaining optimal OAR sparing [6].

In contrast, María Lizondo et al. employed a virtual bolus in a pseudo-skin flash strategy to improve treatment robustness, highlighting the potential of virtual bolus to enhance plan stability and reduce plan renormalization needs. This approach resonates with our findings, where the skin flash tool was used to enhance robustness without compromising target coverage. Furthermore, Ian Gleeson Bachelor et al. demonstrated that VMAT with robust optimization (RO) provided superior stability and target coverage compared to traditional wide tangents (WT), similar to our results, which suggest that advanced optimization methods like skin flash can enhance plan stability and improve overall treatment outcomes [7].

The findings from other studies, such as those by Rakici, Sema Yilmaz et al., and Tugrul Berat Ugurlu et al., also underscore the importance of accounting for intra-fraction motion during treatment. While their research focused on virtual bolus and various skin flash techniques to mitigate motion effects, our study specifically demonstrates the effectiveness of the skin flash tool in both improving target coverage and reducing OAR doses, even when skin dose is slightly increased [4][9].

Additionally, studies by Frédéric A. Miéville et al. and Yipeng He et al. have explored the impact of bolus thickness on treatment outcomes, recommending smaller bolus thicknesses to achieve better target coverage and sparing of OARs. Our findings align with these studies, suggesting that optimizing treatment plans with skin flash can significantly enhance treatment precision and minimize unnecessary radiation exposure to healthy tissues [10][11].

Ian Gleeson, Bachelor et al. compared the robustness of wide tangents (WT) and volumetric modulated arc therapy (VMAT) with various skin flash techniques for breast and nodal radiotherapy. VMAT with robust optimization (RO) provided superior target coverage stability and better nodal coverage than WT while maintaining low organ-at-risk (OAR) doses. VMAT RO was the most robust and efficient approach, minimizing the need for manual adjustments and ensuring consistent performance under anatomical changes [8].

Engstrom, Kenni Hojsgaard et al., Christer Andre Jensen et al., and Yeh, Hui-Ling et al., they have compared the 3DCRT and VMAT deep inspiration breath-hold (DIBH). VMAT was shown to produce better dose distribution compared to 3DCRT while reducing the number of required holds by more than half. These findings demonstrate that incorporating DIBH into the VMAT technique offers superior heart and organ-at-risk (OAR) dose sparing while maintaining target conformity and homogeneity. This highlights the technique's potential for optimizing treatment outcomes in left-sided breast cancer patients. In this study, similar parameters are achieved by using a skin flash tool, which assures that the skin flash tool can be used where advanced techniques like DIBH are not available [12][13][14].

In the study of Wannapha Nobnop et al., skin flash and virtual bolus (VB) methods were evaluated to address intra-fraction movement due to breathing in breast radiotherapy. Their study investigated the skin dose in each planning method by using optically stimulated luminescence on an in-house moving phantom for breast cancer treatment in tomotherapy. Their study confirmed that virtual bolus is an effective method to prevent higher skin dose. Even though our study gives better coverage, there is an increase in skin dose [15].

Sankar, A. et al. used different intensity extension methods and evaluated their impact on entrance dose in breast radiotherapy by using a skin flash tool and virtual bolus. For the defined target volume, IMRT plans give superior dose coverage and dose homogeneity compared to theconventional plans. Intensity extension beyond the skin region must be incorporated in volume- based optimization techniques to account for intra-fraction motion and setup errors. These studies highlight the same point that using skin flash increases the skin dose, which is similar to our study [16].

Anne Caroline Knöchelmann et al. evaluated treatment planning and compared dosimetry plans in free breathing: non-deep inspiration breath-hold (nDIBH) and deep inspiration breath-hold (DIBH). He concludes that DIBH in left-sided breast irradiation is an effective method of reducing the radiogenic heart dose. Similarly, by using the skin flash tool in this study, the heart received the minimal dose, which assures the fact that the skin flash tool is as beneficial as the DIBH technique [17].

Lu Wang et al. have investigated the dose-effect of Auto Flash Margin (AFM) on breast cancer's superficial tissues based on the Treatment Planning System (TPS) in the breast- conserving radiotherapy plan. He concludes that the AFM function application could significantly reduce the possibility of insufficient tumor target caused by inspiratory motion and ensure sufficient tumor target exposure. Likewise, for resolving this issue, our study suggests using the skin flash will give adequate coverage to the target volume during breathing [18].

Brandan A. Dyer, MD, et al. investigated the significant morbidity associated with traditional, large RT fields using 2D or 3D techniques, highlighting the increasing use of intensity- modulated radiation therapy (IMRT) in vulvar cancer. Based on their experience and this study, they recommend using a 2-cm ISF to address variations in daily clinical setup and changes in patient anatomy during treatment. This study also supports our study that using the skin flash can reduce the underdosage of the target during the anatomical variations and intra- and inter- fraction motion during treatment [19].

Milly Buwenge et al. analyzed available evidence from randomized controlled trials (RCTs) on IMRT in BC, particularly in terms of reduction of side effects. He concludes that IMRT seems able to reduce toxicity in selected patients treated with postoperative RT for BC. Similar to Milly Buwenge et al.'s study, there is a reduced toxicity and better coverage to the target volume in the tangential IMRT technique with the skin flash tool during the respiratory motion [20].

Anne Richter et al. have evaluated the impact of breathing motion on postoperative breast cancer radiotherapy. It compared two treatment techniques using 3D CT and 4D CT scans. Both techniques showed similar results, and the motion was reproducible, indicating that breathing motion had a minor impact on the treatment. To this issue, this study gives the better solution by using the skin flash in tangential IMRT plans during the breathing of the patient [21].

Lim Kyoung Dal et al. and Osman Vefa Gul have investigated the skin dose of each plan by measuring and analyzing various thicknesses of skin flash. They have concluded that after using different thicknesses of skin flash, minimizing the thickness of skin flash was considered most ideal because it makes it possible to keep down MUs and lower maximum doses. In this study we have used a 1 cm thickness skin flash, which increases the skin dose. Lim Kyoung Dal et al. used a lesser than 1 cm skin flash, which gives the minimum skin dose compared to the 1 cm skin flash [22][23].

Huseyin Kivanc et al. have compared five different techniques for chest wall (CW) and lymphatic irradiation in patients with left-sided breast carcinoma. He concludes that the dose homogeneity in CW-CTV was better using IMRT techniques compared to 3DCRT, the OAR volumes receiving low radiation doses in the IP-IMRT technique, while volumes receiving high radiation doses were larger with the FP-IMRT technique. Hybrid IMRT plans were found to have the advantages of both FP- and IP-IMRT techniques [23].

Ari-Pekka Honkanen et al. have used pseudo skin flash margin to produce the most robust result.VMAT breast radiotherapy plans with the Acuros XB algorithm. His results suggest extending the PTV 5 mm outside the skin and using an 8 mm thick bolus with a density of 0 HU to produce the most robust result. So, their study proves that using the skin flash in our study gives better coverage [24].

CONCLUSIONS

This study suggests Skin Flash with 10 mm thickness will adequately account for 5 mm breathing shift in the target. Institutions having limited advancement in treatment machines can adapt this method of planning for postoperative breast carcinoma, which will improve better plan quality execution.

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