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# Dosimetric Effects on skin of supine Immobilization Device in Intensity Modulated Radiation Therapy for breast cancer: a retrospective study

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# Dosimetric Effects on skin of supine Immobilization Device in Intensity Modulated Radiation Therapy for breast cancer: a retrospective study

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## Abstract

**Background:** Breast immobilization devices are commonly used in supine breast radiotherapy while the dose perturbation effect is often overlooked in Intensity Modulated Radiation Therapy for breast cancer (BC). This study is to assess the dosimetric effect of supine immobilization devices on skin with a commercial treatment planning system.

**Methods:**40 women with BC were divided into four groups according to the type of primary surgery, group A and B corresponding to patients with left and right BC after radical mastectomy, received a radiotherapy of 50Gy in 25 fractions, group C and D corresponding to patients with left and right BC after breast-conservation surgery,

received a prescription of 40.05Gy in15 fractions and tumor bed simultaneous integrated boost to 45Gy. A 0.2 cm thick skin contour and two sets of body contours were outlined for each patient. Dose calculations were conducted for the two sets of contours using the same plan, the dose difference was assessed by comparing the dose-volume histogram parameter results and by plan subtraction.

**Results:** The supine immobilization devices for BC caused a significantly increase in the skin dose which may finally lead to skin toxicity. The mean dose increased by approximately 0.5Gy and 0.45Gy in left (group A) and right (group B) BC after radical mastectomy, 2.7Gy and 3.25Gy in left (group C) and right (group D) BC after BCS; corresponding to group A, B, C, D, the V10 of skin increased1.27%,1.83%, 1.36%, 2.88% ; the V20 of skin increased 0.85%, 1.87%, 2.76%, 4.86%; the V30 of skin increased 1.3%, 1.24%, 10.58%, 11.91%; the V40 of skin increased 1.29%, 0.65%, 10%, 10.51%. The dose encompassing of planning target volume, as well as the HI and CI, showed little distinction between plan- and plan+.

**Conclusion:** The supine immobilization devices significantly increased the dose of skin, especially for patients with BCS. The immobilization devices should be included in the external contour to account for the dose attenuation and skin dose increment.

**Trial registration:** This is a retrospectively study and it has no intervention on human health care, so this study was not registered.

Key words: Supine immobilization devices; Breast cancer; Intensity Modulated Radiation Therapy; Skin dose

## Background

Breast immobilization devices are commonly used in radiation oncology to provide patient support and improve positional reproducibility during their fractionated radiotherapy. In actual clinical practice, the beam attenuation and build-up perturbations effect caused by the immobilization devices is often overlooked because carbon fiber material are widely used in immobilization devices and are believed to be radio translucent for mega-voltage photons(1). However, the density of carbon fiber is not equivalent to air, attenuation and scattering can occur when the radiation beam pass cross these immobilization systems(2, 3). Previous researches have indicated that immobilization devices used in radiotherapy reduced tumor dose, increased skin dose (bolus effect) and altered dose distribution(4-6). A. De Puysseleyr and his colleagues have reported that irradiating through the carbon fiber immobilization device for prone breast radiotherapy resulted in a considerable beam attenuation (range from 5.33% to 7.57%) and degradation of skin sparing(4). For Chinese BC patients, due to small and compact glands, supine positioning is still the most common approach and has multiple advantages, such as methodological simplicity, comfort and accurate, reproducible positioning, and reduction mean dose to heart(7, 8).

When compared with conventional wedge-based breast radiotherapy, intensity-modulated radiotherapy is capable of delivering highly conformal and homogenous dose distribution to targets and, herein, significantly decrease clinical toxicities such as dermatitis and edema(9-11), which, in turn, substantially increased

the adoption of Intensity Modulated Radiation Therapy (IMRT) during breast radiotherapy(12, 13). However, the increased beams and monitor unit (MU) have an increased propensity to deliver radiation beam through the immobilization devices, and, then, radiation immobilization device attenuation happened, ultimately compromising the target coverage and organs-at-risk (OARs) protection(14). But no study has yet assessed the dosimetric effects of supine breast immobilization devices on the delivered doses to the target volume and OARs for breast IMRT. In this study, we quantified the dosimetric effect of supine immobilization device by comparing the dose distribution calculated with the breast immobilization to that calculated without it, and investigated the potential skin sparing for BC patients achievable with 6 MV photon beams in IMRT plans.

## Methods

### Patient data and setup

Forty women with BC were randomly selected and enrolled in this study; they were divided into four groups according to the type of primary surgery and the lesion location. Patients with left or right BC receiving radical mastectomy were assigned into group A or B respectively. In the same way, patients with left or right BC receiving breast-conservation surgery (BCS) were divided into group C or D respectively. The patients' age ranged from 32 to 65 years, with a median age of 47 years.

### Simulation

All patients were simulated in the head first, supine position using the carbon fiber breast bracket (Klarity Inc, Guangzhou, China) for body immobilization. The supporting board inclined at a certain angle (7°/12°/17°/23° for choose) to assure that the sternum was horizontal. The head was positioned straight on a circle sponge head support, with the chin slightly upwards, avoiding skin folds at the lower neck. Both arms rose over the head using a pair of arm-support to expose the breast adequately, and a knee support to prevent the body sliding down. A thermoplastic film (electron density 0.3~0.7, thickness2.4mm) (Klarity Medical Products, Newark OH) was custom molded over the chest and attached to the bracket by a plastic batten (electron density1~1.1). Computed tomography (CT) image with a 3-mm-slice was performed using a large aperture CT Simulation scanner (Brilliance, Philips Medical System, Amsterdam, Netherlands) (Fig.1). The scan range was from the first cervical vertebra to 2 cm below breast ruffle. The obtained simulation CT images were transferred to the treatment planning system (TPS, Monaco V5.11, Elekta AB, Stockholm, Sweden) for target and OAR delineation and formulate treatment planning.

**Regions of interest**

Regions of interest were delineated on CT images with the CT data set as soft tissue (window 600, level 40) by experienced oncologists according to recommendation of international Commission on Radiation Units and Measurements Reports 83 (ICRU)(15) and China Society for Radiation Oncology (CSTRO) consensus(16). For patients underwent breast-conservation surgery, the clinical target volumes (CTVs) include CTV breast, which includes all mammary glandular tissue,

and CTV boost, which is defined as the tumor bed including clips and seroma plus 5 mm's margin in all directions without exceeding the CTV breast. The corresponding planning target volumes (PTVs) were generated by uniformly expanding 5mm from CTVs respectively. In view of smaller mammary gland of eastern female, the ventral border is designed 3mm below the skin surface(16). For patients with modified radical mastectomy, CTV include chest wall and regional lymph nodes, the ventral border is next to the skin surface(16). Organs at risk (OARs) including heart, left anterior descending artery (LAD), left ventricle (LV), contralateral breast, ipsilateral lung, and contralateral lung were countered for left-side BC, and liver was countered especially for right-side BC. In this study, to assess the surface dose variance from immobilization devices in TPS, the skin contour was especially delineated in the treatment region with 2mm thickness below the skin surface for each patient [Fig.1](17).

As a commercial treatment planning system, an external structure, which should contain the materials involving in calculation, must be defined for calculating the dose distributions. In this study, two sets external body contours were created for each patient: one set included only the patient body without immobilization devices, and the other set included the patient external body contours and the whole breast immobilization devices.

**Treatment planning and dose calculation**

The prescription doses to PTV boost and PTV breast were 45Gy and 40.05Gy, respectively, with a total of 15 fractions in case of BCS. And, in the mastectomy

situation, a prescription of 50Gy in 25 fractions was given. All patients were planned on Monaco TPS with the energy of 6MV, using the dynamic inverse IMRT technique. Multi-beam IMRT employs three groups of similarly-opposed lateral field spaced through a 290° -150° sector for left-side tumors and 200° -60°sector for right-side tumors around the target volume, which includes the breast/chest wall and regional nodes, as indicated in Fig.1. 0° field was added when periclavicular node region was included. A 0.5cm bolus was added to the surface skin in the treatment region for patients with radical mastectomy for compensating the build-up effect of X-ray; on the contrary, bolus was avoided for patients with breast-conserving surgery for improving the cosmetic outcome. The optimization was accomplished by Monaco's build-in Monte Carlo (MC) algorithm combined with Dynamic Multi-Leaf Collimator (DMLC) technology.

For each patient, two IMRT plans were generated. The IMRT plans without immobilization devices taking into calculation were recorded as Plan-. Under the same irradiation constraints, the dose distribution was recalculated with the external body contour containing the immobilization device and this plan was recorded as Plan+.

**Statistical Analysis**

Dose-volume histogram (DVH) was the popular method to evaluate the dose coverage of PTVs and OARs. For the PTVs, the parameters were the mean dose (Dmean), the homogeneity index (HI) and the conformity index (CI). HI and CI were respectively calculated as follow(18, 19).

$$HI = \frac{D_{5\%}}{D_{95\%}} \quad (1)$$

$$CI = \frac{TV1}{TV} * \frac{TV1}{VR1} \quad (2)$$

In formula (1), $D_{5\%}$ and $D_{95\%}$ were the doses received by 5% and 95% of the volume of Region of Interest (ROI), respectively. The HI value closer to 1indicates the better uniformity of dose distribution in target volume. In formula (2)， TV1 is the volume of target that receives the prescription dose and TV is Target Volume. VR1 is the Total Volume within prescription isodose curve. The CI value is between 0 and 1, and higher CI value indicates better dose conformity. For the OARs, the average dose Dmean, sometimes the maximum dose Dmax and the dose-volume were calculated.

For each patient, the dosimetric effect caused by the immobilization devices was calculated by plan subtraction in the TPS. $\overline{D}$ represents the average of parameters difference between Plan+ and Plan- as in formula 3, and $\overline{D}\%$ represents the average of relative difference between Plan+ and Plan-.

$$\overline{D} = \sum_{1}^{10} [(plan+) - (plan-)] / 10 \quad (3)$$

$$\overline{D}\% = \sum_{1}^{10} \{[(plan_n+) - (plan_n-)] * 100 / (plan_n+)\} / 10 \quad (4)$$

The Statistical Package for Social Sciences V22.0 software (SPSS Inc., Chicago, IL, USA) was used to analyze all data. The Wilcoxon matched-paired signed-rank test was used to evaluate the significance of the observed differences between the plan+ and plan-. The differences were considered statistically significant when $p$ <0.05.

**Results**

The comparison of dosimetric difference between Plan- and Plan+ for BC patients receiving radical mastectomy are presented in Table 1 and 2. The parameters

(Coverage Index, Dmean, $D_{2\%}$, and CI) of PTV have little difference, except for HI of left-side cancer ($\overline{D}$ = -0.006) and $D_{98\%}$ of right-side cancer ($\overline{D}$ =0.38 Gy) with indistinctive difference. Due to bolus effect of breast immobilization devices, the mean dose and relative volume receiving 10, 20, 30, and 40Gy of skin were significantly increased for Plan+ ($\overline{D}$ and $\overline{D}\%$ were 0.45Gy and 1.11%, 1.83% and 2.01%, 1.87% and 2.27%, 1.24% and 1.56% and 0.65 and 0.96% for right breast cancer, and 0.50 Gy and 1.25%, 1.27% and 1.37%, 0.85% and 1.00%, 1.30% and 1.67% and 1.29% and 1.99% for left breast cancer, respectively, all $p$<0.05, Fig. 3A). However, there was no statistically significant difference in other OARs.

For patients with breast-conserving surgery, dosimetric effects of immobilization devices were calculated between Plan- and Plan+ too. As showed in Table 3 and 4 and Fig. 2B, plans calculation with breast immobilization devices had higher mean skin dose ($\overline{D}\%$=10.21±2.95% for right breast cancer and 9.07±1.60% for left lesion) and more volume of skin receiving interested dose (10-40Gy) radiation ($\overline{D}\%$ were 3.17%, 5.84%,16.49% and 51.63% for right breast cancer and 1.65%, 3.57%, 15.85%and -151.86% for left breast lesion, Fig. 3B), which again displayed the bolus effect of immobilization devices. For left-side BC patients, the mean dose and relative irradiation volume of interested dose of left lung were decreased with little clinically significance in Plan+ ($\overline{D}$ were -0.21Gy for Dmean, -1.18% for $V_5$, -0.98% for $V_{10}$, -0.47% for $V_{20}$, -0.28% for $V_{30}$, respectively). When it came to planning target volume, the coverage index, HI and CI were also altered with statistical but not clinical significance. As for the other OARs which far away from planning target

198 volume, such as contra-lung, heart, LV, LAD, liver, showed indistinctive difference
199 between two plans.

200 **Dose difference distribution map (Plan+ - Plan-)**

201 The dose difference distribution was calculated by Plan+ subtracted Plan-. As
202 shown in Fig. 2A, the blue to red gradient represented different absolute dose values
203 ranging from -5Gy to 5Gy. The build-up effect and radiation scattering caused by the
204 immobilization devices dramatically altered the dose distribution. The skin dose was
205 observably increased in irradiation region when the immobilization devices were
206 taking into calculation. In other word, the skin dose was underestimated by
207 approximately 6Gy if the immobilization devices were not included in the external
208 contour. Dose in other regions including Lung-L and PTV was decreased, which is
209 similar to DVH and data comparison results.

210 **Discussion**

211 Patient immobilization devices have become an important tool to guarantee
212 accurate delivery of highly conformal dose distribution(20). As the materials used in
213 immobilization devices are not completely X-ray transmission and can cause
214 attenuation of delivering dose, the dosimetric effects of immobilization devices
215 should be included in dose calculations(14, 21) . In addition, the bolus-effect cannot
216 be avoided either. When the beams, especially the posterior oblique orientations ones,
217 passing through the immobilization devices involved in the treatments, the
218 unexpected skin does can be increased and the dosimitric effect would be modified
219 finally(5, 22).

Beam attenuation from the couch, additional inserts and immobilization devices can cause a misrepresentation of the actual dose delivered to the PTV, a deviation by more than the recommended 3% to 5% accuracy range were reported by Olch(20). Li Chen found the attenuation of the head and neck immobilization devices, which reduce dose coverage rate (reduced by from 1.51% to 9.92%) and average dose (reduced by from 0.93% to 1.92%) of planning target volumes in nasopharyngeal carcinoma(21). Alyssa Olson assessed dose variance from immobilization devices in VMAT head and neck treatment planning, and found that plan calculated without immobilization devices was problematic with compromising V95, D100 and PTV coverage(14). However, in our study, there was no clinically important effect of supine breast immobilization devices on dosimetric parameters of PTV and PGTV, with less than 3% deviation. The potential reason may lie in that all radiation beam does not pass through the couch in our study. Puysseleyr *et al.* measured the dosimetric impact of a prone breast immobilization device and found that beam attenuation amounted to 7.6% (6 MV X-ray) for beam pass through the couch top-base plate combination and almost 5% beam attenuation for beam traversing the couch-top(4). Then, there are less than 3% beam attenuation happened when beam passing through base plate only, which is similar to our study.

Radiation-induced skin toxicity (RIST) is one of the predominant side effects for BC patients, and deserves consideration as severe skin toxicity can lead to cession of treatment and cosmetic changes. Francesco *et al.* stated that breast skin receiving dose $\geqq$30Gy is the most predictive parameters of acute RIST(23). While Tsair-Fwu

showed that skin receiving a dose >35Gy (V35) was the most significant dosimetric predictor associated with radiation dermatitis grade 2+ toxicity(24). In our study, a bolus effect of immobilization devices has been observed as the skin mean dose and volume of receiving 10-40Gy are significantly increased in Plan+. This effect is more obvious for patients after BCS. And $V_{30}$ seems to be the most sensitive parameter except for patients with right breast cancer and receiving radical mastectomy. Currently, there is no standard of practice to include immobilization devices within body contour, then actual skin dose was underestimated, which in turn induced more and severer dermatitis. Take all above, we suggest the immobilization devices should be included in dose calculations, and skin of breast region should be delineated as an organ at risk and a dose-volume constraint for skin should be defined whenever possible.

Although the positive results of this study, it has its limitations yet, a larger patient population, different TPS or calculation algorithms, dosimetry techniques and dose measurements are needed for further study.

## Conclusions

In this study, dosimetric effects on skin of supine immobilization devices for BC were calculated and evaluated in IMRT. The data shows the skin dose was significantly increased, especially for patients with BCS, both the V30%andV40% of skin increased sharply more than 10%.This research will remind radiation practitioners to pay attention to the skin dose caused by the immobilization devices and seek solution to remove the negative effects finally, continued research is

imperative. We prefer to include the immobilization devices within external body contour and account for the skin dose increment in the TPS calculation.

## Declarations

### Ethics approval and consent to participate

This study was approved by the Second Affiliated Hospital of Fujian Medical University Ethic Committee [2020(371)]. As the data are anonymous and no intervention was happened in the treatment of patient, the Second Affiliated Hospital of Fujian Medical University Ethic Committee ruled that no formal ethics approval was required in this particular case.

### Consent for publication

Not applicable

### Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

### Competing interests

The authors declare that they have no conflict of interest.

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## Authors' contributions

RL drafted the manuscript, conducted IMRT plans and collected the data. YW conceived and designed this study, contoured the reigns of interest, and revised the manuscript. GY conducted IMRT plans and performed the analysis. YH selected the patient collective and helped to conducted IMRT plans. All authors read and approved the final manuscript.

## Acknowledgements

Not applicable

## Abbreviation

BC: breast cancer; BCS: breast-conservation surgery; IMRT: Intensity Modulated Radiation Therapy; OAR: organs-at-risk; CT: Computed tomography; ICRU: international Commission on Radiation Units and Measurements; CSTRO: China Society for Radiation Oncology; DMLC: Dynamic Multi-Leaf Collimator; LAD: left anterior descending artery; LV: left ventricle; CTV: clinical target volumes; PTV: planning target volumes; ROI: Region of Interest; HI: homogeneity index; CI: conformity index; RIST: Radiation-induced skin toxicity;

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## Figure legend

**Fig. 1,** Display of the immobilization devices in the axial (a) and sagittal view (b). The orange portion is couch, the purple portion is the breast-board, the green portion is the chest fixation mask of thermoplastic, the skin contour is displayed in yellow and the PTV is red.

**Fig. 2,** (a) Dose difference distribution of Cross-sectional plane for a typical patient with left-side breast cancer after BCS. Dose difference was calculated by subtracting Plan- from Plan+. (b) DVH results of Plan- and Plan+ for one typical patient with left-side breast cancer after BCS. The solid lines represent the results of Plan- (calculated without immobilization devices), and the dotted lines represent the results

393 of Plan+ (calculated with the whole immobilization devices included in the external
394 body structure).
395 **Fig. 3,** The $\overline{D}$ % of skin dosimetries for breast cancer after radical mastectomy (a) and
396 after BCS (b). Error bars reflect the standard error of the mean ($r/\sqrt{n}$). The lines are
397 drawn only to guide the eye.
398 **Table 1.** Dosimetric parameters of PTV and OARs of left breast cancer after radical
399 mastectomy.
400 **Table 2.** Dosimetric parameters of PTV and OARs of right breast cancer after radical
401 mastectomy.
402 **Table 3.** Dosimetric parameters of PTV and OARs of left breast cancer after
403 breast-conserving surgery.
404 **Table 4.** Dosimetric parameters of PTV and OARs of right breast cancer after
405 breast-conserving surgery.
406

# Figures

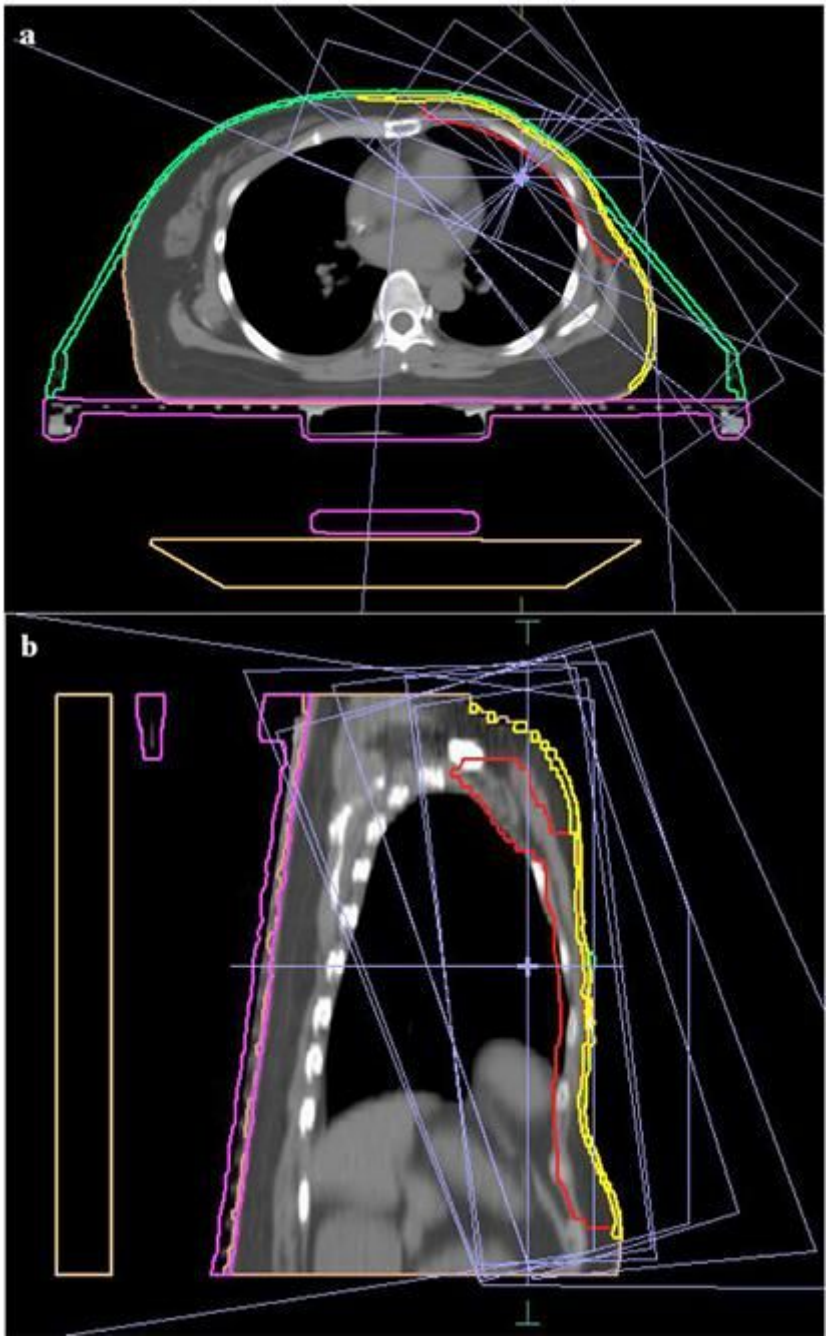
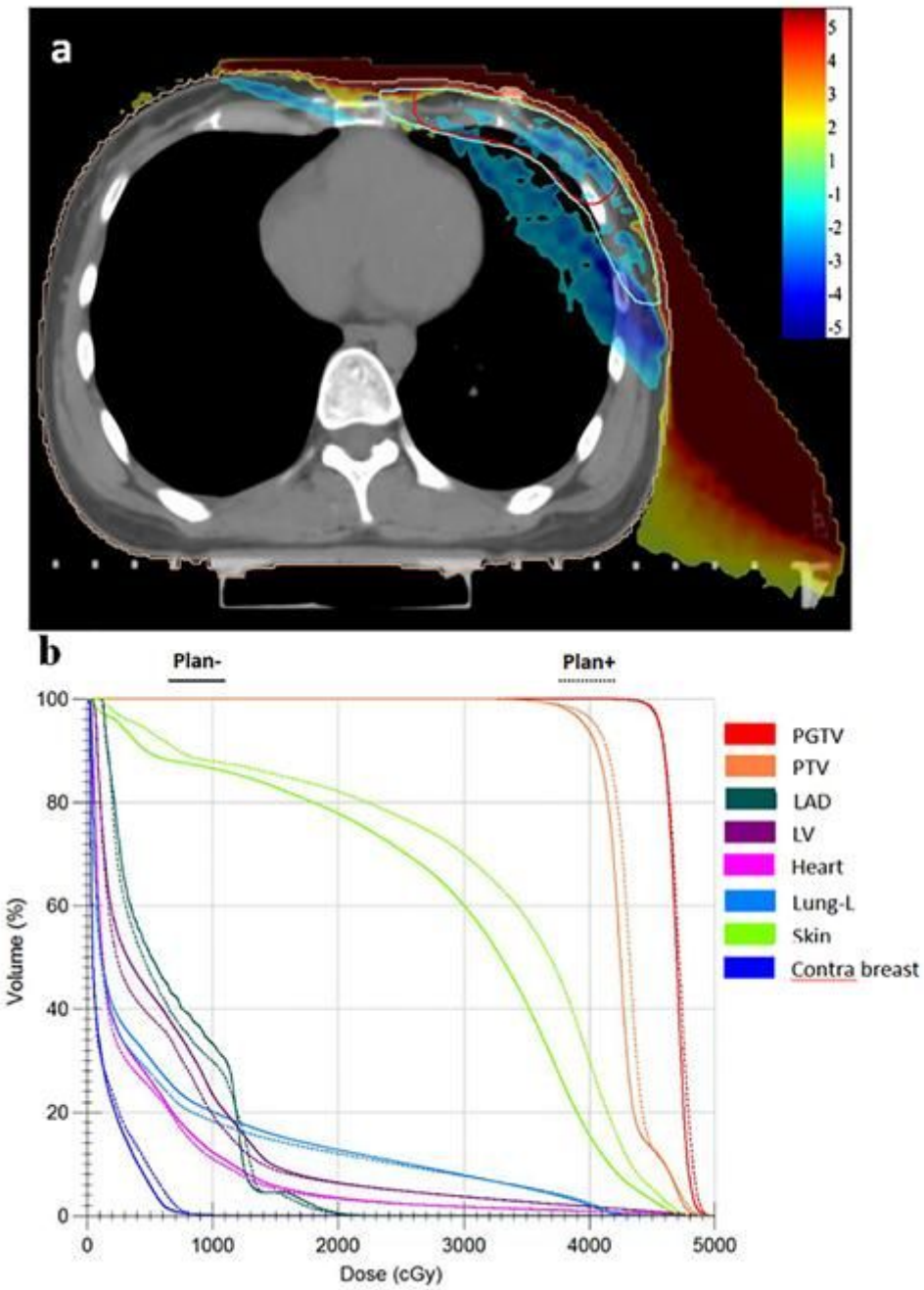


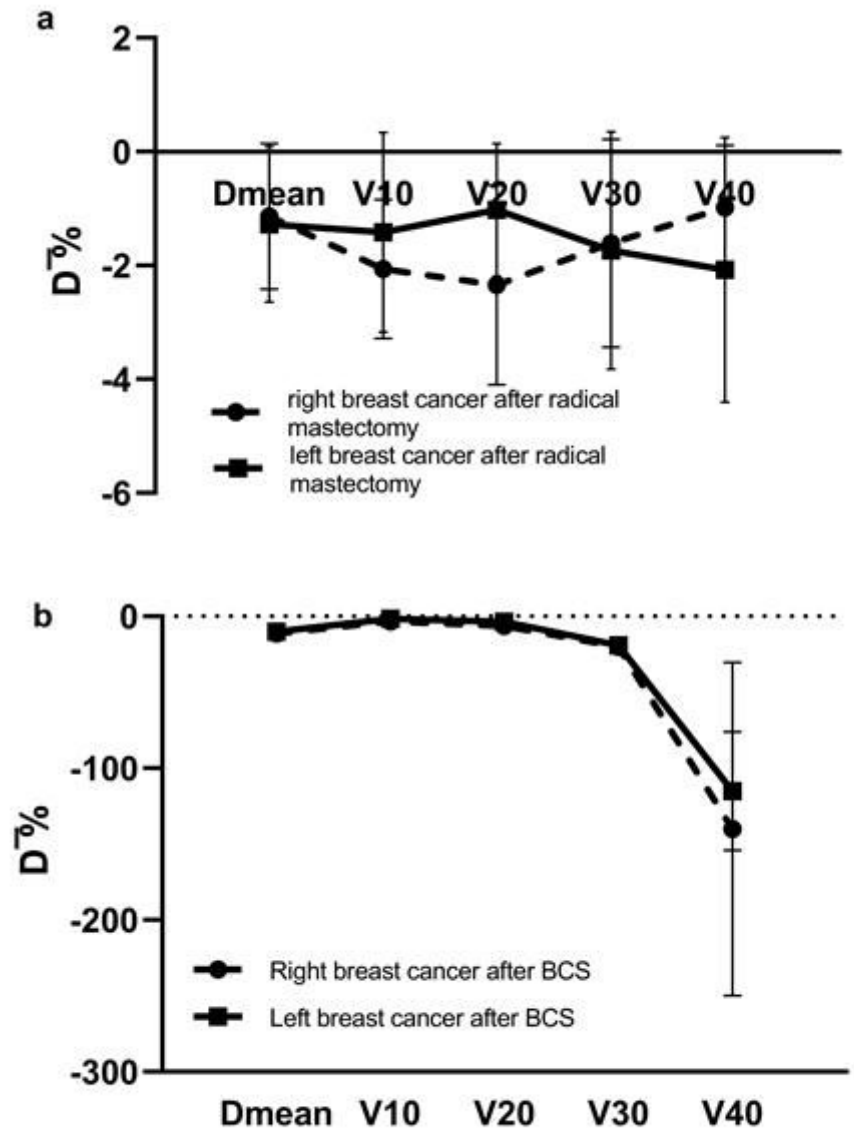

**Figure 1**

Display of the immobilization devices in the axial (a) and sagittal view (b). The orange portion is couch, the purple portion is the breast-board, the green portion is the chest fixation mask of thermoplastic, the skin contour is displayed in yellow and the PTV is red.




## Figure 2

(a) Dose difference distribution of Cross-sectional plane for a typical patient with left-side breast cancer after BCS. Dose difference was calculated by subtracting Plan- from Plan+. (b) DVH results of Plan- and Plan+ for one typical patient with left-side breast cancer after BCS. The solid lines represent the results of Plan- (calculated without immobilization devices), and the dotted lines represent the results of Plan+ (calculated with the whole immobilization devices included in the external body structure).




## Figure 3

The D% of skin dosimetries for breast cancer after radical mastectomy (a) and after BCS (b). Error bars reflect the standard error of the mean (r/n). The lines are drawn only to guide the eye.