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ORIGINAL ARTICLE

Use of immobilisation bra for daily setup of patients with pendulous breasts undergoing radiotherapy

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Abstract

Purpose A feasibility study to evaluate the Chabner XRT® Radiation Bra (CIVCO Radiotherapy & Qfix, Coralville, IA, USA) as a customised immobilisation device for patients with pendulous breasts undergoing radiotherapy was conducted.

Methods A total of 34 patients with large pendulous breasts were fitted with the Chabner XRT® Radiation Bra during RT. A mixed-method questionnaire was administered to both radiation therapists (RTTs) and patients. RTTs evaluated the effectiveness of the bra in setup. Patients appraised its comfort level and ease of wearing. Setup reproducibility was evaluated based on a departmental imaging protocol. Acute skin side effects were documented with photos and assessed using the Radiation Therapy Oncology Group (RTOG) classification.

Results Of the patients, 27 (79.4%) completed the questionnaire. 23 patients felt comfortable wearing the bra while 20 felt less exposed during treatment. Reproducibility was acceptable, with a median (range) setup error (isocentre) of 0.0 cm (–0.6 to 0.7 cm; left/right), –0.1 cm (–0.5 to 1.2 cm; posterior) and 0.2 cm (–0.5 to 0.9 cm; inferior) achieved based on matched field borders on skin. However, repeated setups and imaging were required for 3 patients due to large breast size (cups D–G; size 4–5). Minimal skin toxicity (grade 0–1) was observed. No grade ≥ 2 was reported. 10 RTTs completed the survey. Male RTTs ($n = 4$) were not confident in assisting patients with bra fitting. 8 RTTs agreed that although it was difficult to reproduce the breast tissue for treatment, it helped patients to maintain the treatment position.

Conclusion Our study demonstrated the feasibility of using a customised bra which provided optimal setup reproducibility while maintaining minimal skin toxicity and patient comfort, especially the value-added modesty felt among Asian women during their breast cancer radiotherapy.

Keywords Immobilisation bra · Chabner bra · Breast radiotherapy · Patient positioning · Breast cancer

Introduction

Breast cancer is the most common female malignancy in Singapore, accounting for 29.4% of all female cancer. It is also the top cause of death by cancer in the female population in Singapore [1]. The standard of care in breast cancer management for women who underwent breast-conserving surgery followed by adjuvant radiation therapy (RT) has good local control rates of up to 95% and comparable mortality rates to mastectomy [2–4]. Radiotherapy also plays a significant role in reducing local recurrences for node-positive disease [2, 4]. Acute skin toxicity is common in breast RT. It ranges from mild erythema to dry or wet skin desquamation, with the peak reaction often occurring one to two weeks posttreatment [5]. The observed normal tissue toxicity rates and breast cosmetic outcome not only depend on treatment techniques but also on patient-related factors, especially breast size and shape [6, 7]. It is a widely accepted fact that patient-related factors such as higher body mass index (BMI) and larger breast size increase the risk of grade ≥ 2 dermatitis (Radiation Therapy Oncology Group [RTOG] skin toxicity scoring) regardless of the fractionation regimen [5, 7]. Therefore, patients with pendulous breasts are prone to increased skin reaction due to exces-

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sive skin folds, especially in the inframammary region due to loss of skin sparing [8, 9].

Another concern for this group of patients is the poor reproducibility of daily treatment setup [10, 11]. Daily setup reproducibility has always been a challenge because of the inherent mobility of large breasts. When these patients lay supine during treatment, their breasts either gravitate to the side or superiorly [12]. As a result of this mobility, a large volume of lung tissue was often included in the treatment volume while trying to ensure adequate posterior coverage of the breast [13]. Consequently, women with large pendulous breasts are subjected to more radiation-induced toxicity compared to women with smaller breasts. It is therefore necessary to immobilise the breast effectively for daily treatment setup reproducibility to reduce severity of these reactions.

Presently, at our institution, a prone treatment position is used for women with large pendulous breasts to reduce the inframammary skin folds. The prone position provides a simple alternative to supine breast RT for patients with pendulous breasts, with better dose homogeneity and lower doses to organs at risk (OARs), whereby the supine position would have resulted in inacceptable dose inhomogeneity [14–16]. However, this technique is not suitable for tumours located medially due to close proximity to the contralateral breast; likewise, it is not suitable for treating cases with nodal involvement [17].

In terms of patient accessibility and comfort, patients with limited physical mobility and/or capability may have difficulty in mounting the prone device. Lying in a prone treatment position over a prolonged period can also be uncomfortable [18].

More recently, the use of a bra during breast irradiation has demonstrated improved setup stabilisation and positive dosimetric results associated with a reduced heart volume in the treatment volume [19]. Furthermore, Keller et al. has shown that use of bra is a good alternative to prone positioning and associated reduced chest wall separation and heart volume within the treatment field [19]. In this study, we evaluated the use of the Chabner® Radiation Bra (CIVCO Radiotherapy & Qfix, Coralville, IA, USA) as a customised breast immobilisation device to provide optimal support for breast cancer patients with pendulous breasts undergoing RT.

Materials and methods

This was a prospective study on the use of an immobilisation bra for daily setup of patients with pendulous breasts undergoing breast radiotherapy between September 2019 and August 2020. Patients were followed up at our institution according to the routine surveillance protocol. Ethical approval was obtained (CIRB ref. 2019/2419). This study has been approved by the appropriate ethics committee and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

The population included female patients with pendulous breasts who underwent lumpectomy followed by adjuvant RT. All patients were treated with three-dimensional conformal radiotherapy (3DCRT). Two dose regimens were used depending on the histology and grading of the tumour: the standard treatment dose protocol of a total of 40 Gy over 15 fractions [20] or the fast-forward protocol prescription of 26 Gy delivered in 5 fractions [21]. Patients were treated with or without a tumour bed boost of 10.5 Gy in 3 fractions or 10 Gy in 5 fractions [22].

During CT simulation, radiation therapists (RTTs) and radiation oncologists (ROs) determined which patients were eligible for the use of an immobilisation bra for RT. The criteria were based on the size (cup C and above) and shape of the breasts as well as the amount of lung involved in treatment volume (> 3.5 cm) if immobilisation was not used. The risk of adverse skin erythema due to skin folds was also a major consideration.

Immobilisation bra

The Chabner XRT® Radiation Bra is made of lightweight radiolucent material that supports the patient's breast in the desired treatment position. Treatment landmarks are visible through the thermoplastic polyurethane (TPU) material of the bra, which are pertinent for daily setup reproducibility. This bra has also been tested at 6 MeV and 6 MV to demonstrate that the radiation beam can pass through treatment areas of the bra without attenuation. The Velcro attachment can be indexed and, hence, the fitting of the bra on the pa-

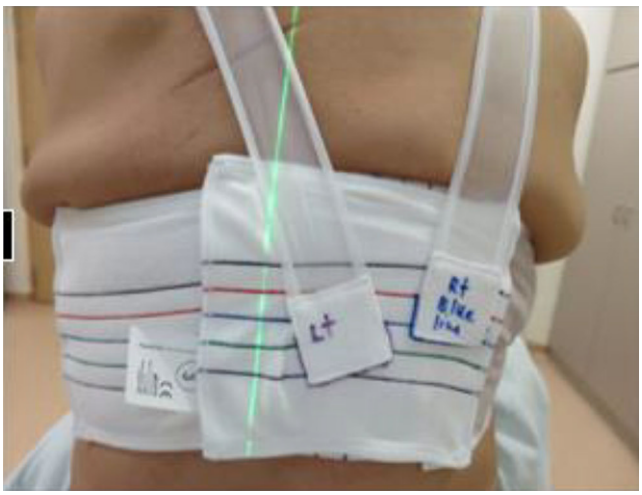

Fig. 1 Velcro attachment that can be indexed to customise the fit of the bra

tients can be customised at CT simulation and reproduced for daily treatment setup (Fig. 1).

Treatment positioning and setup accuracy

All patients were treated lying supine on a MT350 breast board (CIVCO) with both arms up and their knees resting on an indexed grey angular cushion on the treatment couch. Setup reproducibility was evaluated based on the departmental imaging protocol, whereby imaging was performed for all new cases on the first two days of RT. 2D/2D image registration of the orthogonal MV isocentre images was performed on the first day of treatment, which was ascertained by the treatment borders. Treatment images were compared with the planning reference images by the RTTs to calculate the setup error in millimetres in the three planes: left/right, anteroposterior and superoinferior, or Rt(+)/Lt(–), Ant(+)/Post(–) and Sup(–)/Inf(+), respectively. All beam's-eye-views (BEV) were imaged on the first day followed by the medial glancing and/or supraclavicular fields which were imaged on the second day and once a week thereafter for the standard dose prescription, and daily imaging for patients on fast-forward protocol prescription.

Dosimetric comparison

To provide a dosimetric comparison between breast patients with similar breast volumes treated with or without the use of the immobilization bra, 5 left-sided and 5 right-sided breast plans were sampled from this study and compared with a previously treated cohort of patients (supine without bra). Data were matched based on similar anatomical parameters such as breast separations measured from the anterior surface to the posterior field edge along the central axis and the beam path from the medial to lateral field edge. Plan parameters such as volume of lung receiving 20 Gy and mean heart dose were compared between the two groups of patients.

Skin toxicity

Patients' skin was assessed using the RTOG toxicity score system during weekly review with radiation oncologists. Patients' skin was photographed to document the weekly changes in skin reactions. Patients were also seen routinely postradiotherapy at 2 weeks, 1 month, and 3 months.

Mixed method questionnaire

Two different questionnaires were administered (Supplementary Materials), one for staff and one for patients. RTTs who were directly involved in the CT simulation procedure and in administering daily treatment for the patients were asked to complete a questionnaire. This questionnaire required the RTTs to assess the issues related to the use of Chabner XRT® Radiation Bra as an immobilisation device for breast treatment through a series of questions focusing on its effectiveness and ease of use with a combination of yes/no and Likert scale questions. The RTTs were asked to grade individual responses using the Likert qualitative data into quantitative format, hence allowing numerical and statistical comparisons.

At the end of treatment, patients were asked to evaluate their comfort level when wearing the Chabner XRT® Radiation Bra by grading using the Likert scale of 1–4, with 1 representing "not at all" to 4 being "very much". The patients were also asked for their feedback on the ease of wearing the Chabner XRT® Radiation Bra. More often than not, patients going through radiation therapy treatment were required to expose their upper body. Taking their modesty into consideration, this study also assesses whether their modesty would be less compromised when wearing the Chabner XRT® Radiation Bra for radiation therapy.

Table 1 Patient demographics

Characteristic	*n*	%
Total patients	34	100
Age (years)		
Mean (range)	59.5	(41–80)
Ethnicity		
Chinese	17	50
Malay	6	18
Indian	10	29
Eurasian	1	3
Laterality		
Left breast	17	50
Right breast	15	44
Bilateral breasts	2	6
Staging (pathological)		
Stage 0–1	23	68
Stage 2	10	29
Malignant phyllodes	1	3
Surgery		
Breast-conserving	30	88
Simple mastectomy and axillary clearance with reconstruction	4	12
Prescription		
40 Gy in 15 fractions (START)	5	15
40 Gy in 15 fractions with boost	10	29
26 Gy in 5 fractions (fast forward)	7	21
26 Gy in 5 fractions with boost	11	32
60 Gy in 30 fractions	1	3

Statistical analysis

The data collected were coded in a Microsoft Excel sheet (Microsoft, Redmond, WA, USA) and the translational errors were presented as mean ± standard deviation (SD). A one-sample *t*-test was performed (significance level $p < 0.05$, 95% CI), to determine whether the mean setup error in the recruited subjects was equal to 0. The analysis was performed using PASW for windows, version 26.0 (IBM Corp., Armonk, NY, USA).

Results

A total of 34 patients (patients' demographics are summarised in Table 1) with large pendulous breasts were fitted with the Chabner XRT® Radiation Bra between September 2019 and August 2021 (Fig. 2). 15 patients received the standard treatment dose protocol of a total of 40 Gy over 15 fractions, with 10 of them receiving a boost dose of 10 Gy in 3 or 5 fractions; 1 of the patients received 16 Gy as a boost dose owing to positive margins. 18 patients received the fast-forward protocol prescription of 26 Gy delivered in 5 fractions, with 11 patients receiving a boost dose of 10.5 Gy in 3 fractions and 1 patient receiving 12 Gy in 4 fractions due to positive margins. One patient was prescribed 60 Gy in 30 fractions for her malignant phyllodes.

Setup reproducibility

Reproducibility of the treatment position was acceptable based on the matched field borders on skin for daily RT. The observed mean (SD) of setup errors in the three planes were within 2 mm (Table 2). Repeated setups and imaging

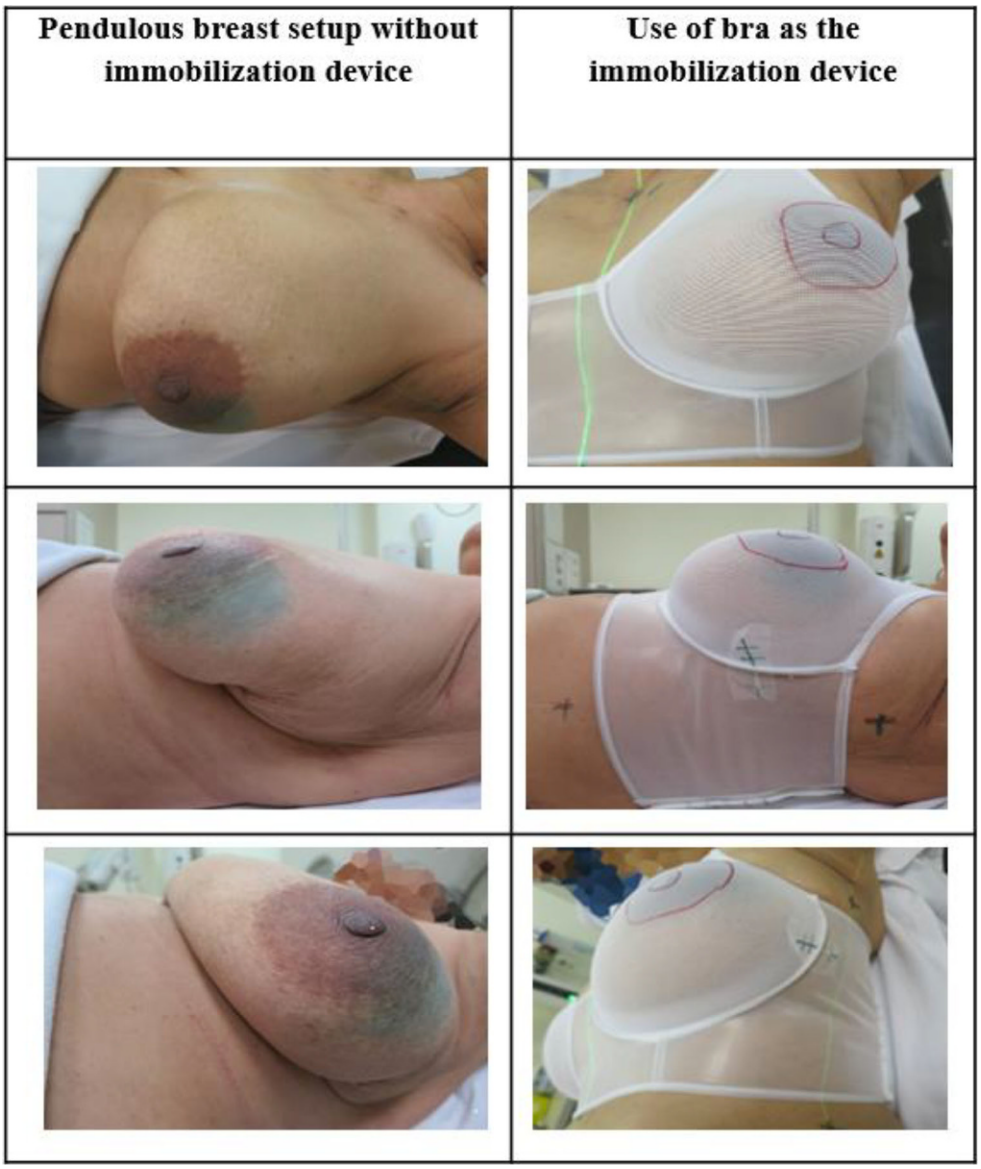

Fig. 2 Comparison of supine position of breast tissues with and without bra

Table 2 Mean (SD) of setup errors observed in the three planes

One-sample statistics				
	N	Mean	Std. deviation	Std. error mean
LT_RT	34	0.0412	0.35600	0.06105
ANT_POST	34	–0.1059	0.27296	0.04681
SUP_INF	34	0.1176	0.44208	0.07582

Lt left, *Rt* right, *Ant* anterior, *Post* posterior, *Sup* superior, *Inf* inferior, *N* number

Table 3 Setup errors of patients ($n = 34$) fitted with the Chabner® Radiation Bra (CIVCO Radiotherapy & Qfix, Coralville, IA, USA)

One-sample test						
	Test value = 0					
	t	Df	Sig. (2-tailed)	Mean difference	95% CI of the difference	
					Lower	Upper
LT_RT	0.674	33	0.505	0.04118	–0.0830	0.1654
ANT_POST	–2.262	33	0.030	–0.10588	–0.2011	–0.0106
SUP_INF	1.552	33	0.130	0.11765	–0.0366	0.2719

Lt left, *Rt* right, *Ant* anterior, *Post* posterior, *Sup* superior, *Inf* inferior, *Sig.* significance (*p*-value), *CI* confidence interval

were required for 3 patients due to large breasts size (cups D–G; size 4–5). In accordance with the departmental breast imaging protocol, there was good agreement (≤ 0.5 cm) between the treatment portal image BEVs and planning generated BEVs.

Ant/Post setup errors are statistically significantly drifted by 0.1 mm (95% CI –0.01 to –0.2) towards the posterior direction from the isocentre plane, t(33) = –2.262, $p = 0.03$ (Table 3). There was no statistically significant difference observed in the Lt/Rt and Sup/Inf planes from isocentre plane.

Dosimetric comparison

All the left-sided breast cases treated with the Chabner XRT® Radiation Bra reported a lower mean heart dose (1.24 Gy vs. 2.9 Gy) compared to those without. Similarly, they had lower V20Gy of the left lung compared to those

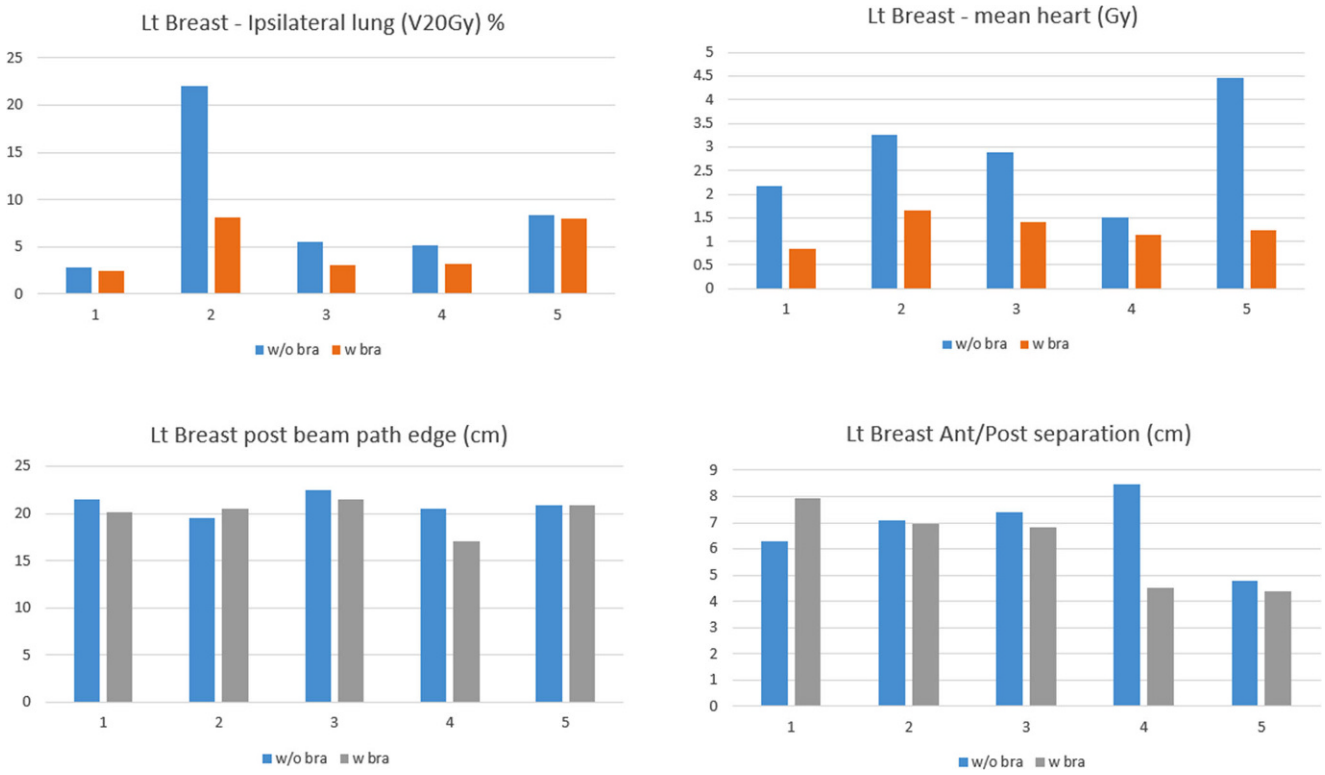

Fig. 3 Comparison of left-sided heart and lung sparing for patients treated without vs. with bra. *Lt* left, *Ang* anterior, *Post* posterior, *w/o* without, *w* with

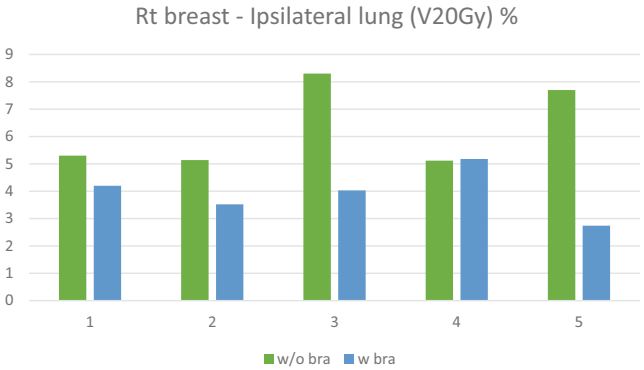

Fig. 4 Comparison of right-sided lung sparing for patients treated without vs. with bra. *Rt* right, *w/o* without

without (3.15% vs. 5.57%; Fig. 3). For the right-sided cases, 4 out of 5 patients treated with the Chabner XRT® Radiation Bra had lower V20Gy of the right lung compared to those without (4.03% vs, 5.3%; Fig. 4).

Skin toxicity

Minimal skin toxicity (grade 0–1) was observed for all patients at the end of the treatment. During the weekly review with the radiation oncologists, grade 0 skin toxicity was documented for 6 patients while 24 patients experienced grade 1 skin reactions; 4 patients had grade 2 skin toxicity, and none had grade 3 skin toxicity throughout the course of treatment. The RTTs at the treatment unit took photographs of the patients' skin to document the changes in skin reactions. These photographs focused mainly on the skin changes at the inframammary skin fold and axillary regions (Fig. 5).

Mixed method questionnaires

Out of the 34 patients, 27 patients completed and returned the self-administered survey (response rate 79.4%); 3 patients were not given the questionnaire, while 3 other patients did not complete the questionnaire; 1 patient took the questionnaire home but did not return the form. Among those who responded, the majority of the patients ($n=23$) felt comfortable wearing the immobilisation bra throughout their course of RT and 20 patients reported that wearing the bra made them felt less exposed during RT; 2 patients complained of slight pain when wearing the bra for RT and 1 patient found the bra uncomfortable and too tight.

The questionnaire was completed by 10 RTTs who were involved in the treatment of these patients . All male RTTs ($n=4$) were not confident in assisting patients with the fitting of the bra. 8 RTTs agreed that although it was slightly more difficult to reproduce the breast tissue for daily treatment, it had helped patients to maintain the treatment position throughout the procedure.

Discussion

One of the challenges in positioning large and/or pendulous breasts in the supine treatment position is the excessive skin folds, particularly at the inframammary area, resulting in dose inhomogeneity in the target and increasing acute and late skin toxicities [8, 9]. Another concern is the poor setup reproducibility for this group of patients for their daily RT, as the breast tissue may displace differently [10–12]. In addition, the lateral displacement of the breast tissue resulted in excess lung tissue in the treatment volume in order to ensure adequate coverage of the posterior portion of the breast [13]. For left-sided breast treatment, this displacement also resulted in an increasing incidental dose delivered to the heart [9, 15].

Several studies have reported on the different techniques and immobilisation gadgets to achieve satisfactory breast immobilisation for patients with pendulous breasts undergoing RT. These included the use of breast ring, thermoplastic shell, commercial bra and a prone breast board [8, 12, 18, 19]. For years, our centre had been using the prone treatment setup position for this pool of patients. The prone

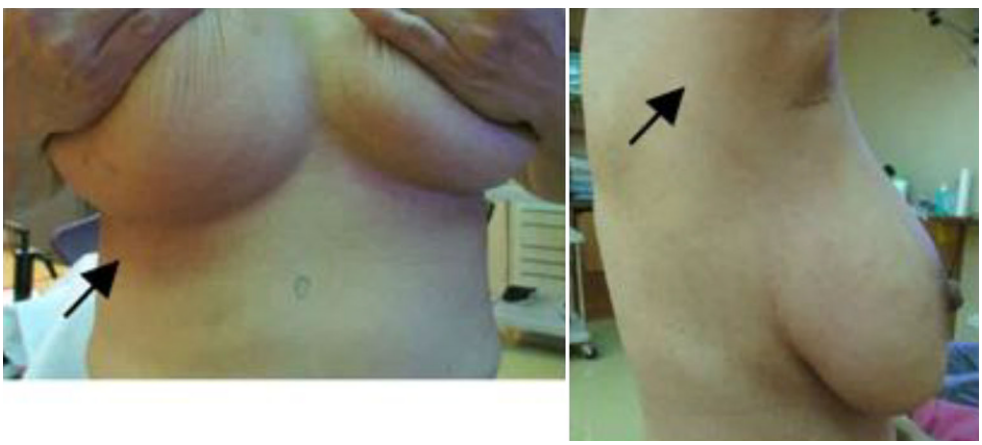

Fig. 5 Minimal skin reaction at inframammary and axillary regions

position allows the breast tissue to fall naturally due to gravity, resulting in a fairly good shape for improved dose homogeneity in the target volume [16]. Studies have also shown that the prone position allows a bigger distance between the chest wall and the target area, resulting in a lower dose to the lung and heart with less acute toxicity and better cosmesis [23, 24]. However, the prone position comes with its own challenges and limitations, which include reduced setup precision and discomfort [18, 25]. Patients often complain of pain at the sternum region near the edge of the board support for the contralateral (nontreated) breast. Moreover, this prone position may not be well tolerated by patients with physical disabilities or medical commodities. Patients with lymph node dissection have reported difficulties in keeping both their arms up for RT in the prone position. Supraclavicular and regional lymph node irradiation can be difficult to execute in the prone position, as the components of the prone breast board that support the patients' arms and head are in the anterior beam pathway [17, 26].

This paper presents an alternative technique to treat patients with pendulous breasts in a comfortable reproducible position and yet achieve the acceptable dosimetry outcomes as in prone position. As opposed to the prone position, a supine treatment position that can accommodate high tangents and regional node irradiation may be an advantage. Earlier studies compared the use of a thermoplastic shell and commercially available bra to immobilise the breast in a reproducible position for RT [19, 27]. Recently, Mulla et al. compared setup reproducibility and skin toxicity between the use of a thermoplastic shell and commercial bra for pendulous breast RT [27]. In their study, although the setup errors in the longitudinal and lateral planes performed better, the setup errors in the vertical plane displayed a poorer performance compared to the bra. The authors attributed this to the rigidity of the shell that caused the breast to flop downwards after setting the shell [27]. In another study, the authors also recommended daily setup corrections to ensure treatment accuracy for breast treatment using shell [28]. In our study, the Chabner XRT® Radiation Bra can be custom fitted to each patient to provide a better fit to the breast shape. Compared to the stiff thermoplastic shell, the Chabner XRT® Radiation Bra is softer and comfortable to wear throughout the treatment procedure and yet able to immobilise the breast as effectively as the shell for daily setup. The reproducibility of this immobilisation bra was demonstrated by the small (comparable) median setup errors for the lateral, longitudinal, and vertical planes, with error values less than 0.5 cm (the minimal margins to avoid performing daily setup corrections). This custom-fitted bra can support the pendulous breast and decrease the amount of loose soft tissue lateral to the breast, thereby improving setup reproducibility. On the other hand, there were 3 patients whose setup errors were larger than 0.5–0.8 cm in all three planes; hence, daily imaging was required to ensure setup accuracy. This could be due to the large breast sizes (cups D–G; size 4–5) or the incorrect selection of the bra; hence, the breast tissue was not as effectively immobilised for daily treatment setup. In contrast to the opaque thermoplastic shell, the translucency of the bra enables the RTTs to visualise the patient's skin marks, bony landmarks and the surgical scar through the TPU windows on the bra. This allowed the RTTs to accurately position the breast tissue within the immobilisation gadget for daily treatment.

In 2013, Keller and her team studied the use of commercially available bras to augment the breast shape and position in large-breasted women. With the use of a bra, they successfully demonstrated a significant reduction in heart and lung volume in the treatment volume for left-sided tumours [19]. This is concordant with the findings from this study, where a lower mean heart dose was observed in all the patients treated with the bra compared to those treated without. These favourable results were also observed for the left and right lungs in terms of an overall lower percentage of lungs receiving 20 Gy compared to patients treated without the bra. However, it is also pertinent to acknowledge that the plan comparison was limited to a retrospective analysis with a different cohort of patients treated without the Chabner XRT® Radiation Bra.

In our study, we observed that the Chabner XRT® Radiation Bra aids in minimising lateral displacement of the breast tissue while lifting the breast to reduce the skin fold at the inframammary area. Our patients fared better in terms of acute skin toxicity than those in Keller et al.'s research, which used a commercially available bra or bustier. While their investigation found a higher prevalence of grade 2 to 3 skin toxicity with a more than fivefold risk, all 34 patients in our study had only grade 0–1 skin toxicity. One reason cited in their study was that there were more large-breasted patients selected for the bra cohort and larger breast size itself had always been associated with increased dose inhomogeneity and acute skin toxicity. Furthermore, Keller and team believed that there may be a possibility that the bra did not eliminate all skin folds at the inframammary or axillary regions [19]. Another rationale for not using a thermoplastic shell in our study is that it has a bolus effect, which increases surface dosage and thus skin toxicity [29]. Interestingly, in Mulla's study, the patients suffered fewer grade 2 to 4 skin reactions compared to the patients who were treated using a commercial bra [27]. The patients immobilised with a shell were prescribed the hypofractionated protocol (4240 cGy in 16 fractions or 4005 cGy in 15 fractions), whereby the patients using a commercial bra were treated with the standard protocol of 5000 cGy in 25 fractions. It is an established fact that patients who are treated with hypofractionated regimens experienced less acute skin

toxicity [30]. This could explain why the patients in Mulla's trial who were immobilised in shells had less skin toxicity than the bra cohort. There was relatively minimum skin toxicity reported in our study too, because the patients were given either a hypofractionated or a fast-forward regimen. The skin toxicity results were consistent with the results from the FAST-Forward trial [31].

The questionnaire employed in this study was self-administered. Since it was not compulsory for patients to complete and/or return the survey, this resulted in incomplete or missing survey forms. Despite the missing data, the findings reported here were deemed reliable and significant because the response rate remained high at 80%. Patient comfort and modesty were also evaluated in this study, which were not assessed in several earlier studies looking into patient immobilisation devices [19, 27]. In the Asian culture, patients often feel embarrassed to undress for their RT, especially in the presence of male RTTs. In this study, the bra was reported to protect the modesty of the patients, thus making them feel more at ease during RT. Results from the staff questionnaires showed that male staff were more uncomfortable and less competent with regards to treating patients with the Chabner XRT® Radiation Bra. An educational video, together with the use of a customised female mannequin, was produced to allow both female and male staff more hands-on practice to increase their competence level before assisting the patients. The mannequin allows the staff, especially the male staff, to learn the correct way of helping female patients with the Chabner XRT® Radiation Bra without any awkwardness. This boosts the staff's confidence in treating patients with Chabner XRT® Radiation Bra.

In this study, late skin toxicity was not reported due to the short follow-up. Furthermore, no acute skin toxicity comparisons were conducted between women with pendulous breasts wearing the Chabner XRT® Radiation Bra and those who did not use any immobilisation device. This may limit the generalisability of the findings, particularly when comparing the risk of acute skin toxicity.

Conclusion

The Chabner XRT® Radiation Bra was sufficient to immobilise the pendulous breast for reproducible setup for daily RT and provided an alternative and comfortable technique to prone positioning in the treatment of pendulous breast patients to improve dose homogeneity for breast RT. An improvement in homogeneity and reduced acute toxicity could improve long-term cosmetic outcomes. Our study demonstrated the feasibility of using a customised breast immobilisation device, which provided optimal setup reproducibility while maintaining minimal skin toxicity and patient comfort and especially the value-added modesty felt among Asian women during their breast cancer radiotherapy. This study also showed the positive correlation of the incidence and severity of skin toxicity with the total treatment dose received.

Supplementary Information The online version of this article (https://doi.org/10.1007/s00066-023-02131-4) contains supplementary material, which is available to authorised users.

Declarations

Conflict of interest J.Z. Chua, L.H. Lim, E.P.P. Pang and G. Kusumawidjaja declare that they have no competing interests.

Ethical standards All procedures performed in studies involving human participants or on human tissue were in accordance with the ethical standards of the institutional and/or national research committee and with the 1975 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

References

1. Office NRoD (2019) Singapore cancer registry annual report 2019
2. McDonald ES, Clark AS, Tchou J, Zhang P, Freedman GM (2016) Clinical diagnosis and management of breast cancer. J Nucl Med 57(Suppl 1):9S–16S
3. Jatoi I, Proschan MA (2005) Randomized trials of breast-conserving therapy versus mastectomy for primary breast cancer: a pooled analysis of updated results. Am J Clin Oncol 28:289–294
4. Haviland JS, A'Hern R, Bentzen SM, Whelan T, Bliss JM (2014) Radiotherapy for breast cancer, the TARGIT-A trial. Lancet 383:1716–1717
5. Pignol JP, Vu TT, Mitera G, Bosnic S, Verkooijen HM, Truong P (2015) Prospective evaluation of severe skin toxicity and pain during postmastectomy radiation therapy. Int J Radiat Oncol Biol Phys 91:157–164
6. Meattini I, Guenzi M, Fozza A, Vidali C, Rovea P, Meacci F et al (2017) Overview on cardiac, pulmonary and cutaneous toxicity in patients treated with adjuvant radiotherapy for breast cancer. Breast Cancer 24:52–62
7. Ratosa I, Jenko A, Oblak I (2018) Breast size impact on adjuvant radiotherapy adverse effects and dose parameters in treatment planning. Radiol Oncol 52:233–244
8. Bentel GC, Marks LB, Whiddon CS, Prosnitz LR (1999) Acute and late morbidity of using a breast positioning ring in women with large/pendulous breasts. Radiother Oncol 50:277–281
9. Das IJ, Cheng CW, Fein DA, Fowble B (1997) Patterns of dose variability in radiation prescription of breast cancer. Radiother Oncol 44:83–89
10. Freedman GM, Anderson PR, Li J, Eisenberg DF, Hanlon AL, Wang L et al (2006) Intensity modulated radiation therapy (IMRT) decreases acute skin toxicity for women receiving radiation for breast cancer. Am J Clin Oncol 29:66–70
11. Goodman KA, Hong L, Wagman R, Hunt MA, McCormick B (2004) Dosimetric analysis of a simplified intensity modulation technique for prone breast radiotherapy. Int J Radiat Oncol Biol Phys 60:95–102
12. Latimer JG, Beckham W, West M, Holloway L, Delaney G (2005) Support of large breasts during tangential irradiation using a micro-shell and minimizing the skin dose—a pilot study. Med Dosim 30:31–35

13. Remouchamps VM, Letts N, Yan D, Vicini FA, Moreau M, Zielinski JA et al (2003) Three-dimensional evaluation of intra- and interfraction immobilization of lung and chest wall using active breathing control: a reproducibility study with breast cancer patients. Int J Radiat Oncol Biol Phys 57:968–978
14. Buijsen J, Jager JJ, Bovendeerd J, Voncken R, Borger JH, Boersma LJ et al (2007) Prone breast irradiation for pendulous breasts. Radiother Oncol 82:337–340
15. Ferrari A, Ivaldi G, Leonardi MC, Rondi E, Orecchia R (2009) Prone breast radiotherapy in a patient with early stage breast cancer and a large pendulous breast. Tumori 95:394–397
16. Merchant TE, McCormick B (1994) Prone position breast irradiation. Int J Radiat Oncol Biol Phys 30:197–203
17. Moody AM, Mayles WP, Bliss JM, A'Hern RP, Owen JR, Regan J et al (1994) The influence of breast size on late radiation effects and association with radiotherapy dose inhomogeneity. Radiother Oncol 33:106–112
18. Barrett-Lennard MJTS (2013) Comparing immobilisation methods for the tangential treatment of large pendulous breasts. Radiographer 55:7–13
19. Keller L, Cohen R, Sopka DM, Li T, Li L, Anderson PR et al (2013) Effect of bra use during radiotherapy for large-breasted women: acute toxicity and treated heart and lung volumes. Pract Radiat Oncol 3:9–15
20. Group ST, Bentzen SM, Agrawal RK, Aird EG, Barrett JM, Barrett-Lee PJ et al (2008) The UK Standardisation of Breast Radiotherapy (START) Trial A of radiotherapy hypofractionation for treatment of early breast cancer: a randomised trial. Lancet Oncol 9: 331–341
21. Murray Brunt A, Haviland JS, Wheatley DA, Sydenham MA, Alhasso A, Bloomfield DJ et al (2020) Hypofractionated breast radiotherapy for 1 week versus 3 weeks (FAST-Forward): 5-year efficacy and late normal tissue effects results from a multicentre, non-inferiority, randomised, phase 3 trial. Lancet 395:1613–1626
22. Coles C (2020) Guidelines on radiation therapy for breast cancer during the COVID-19 pandemic. www.rcr.ac.uk/cancer-treatment-documents. Accessed 1 June 2022
23. Mulliez T, Veldeman L, van Greveling A, Speleers B, Sadeghi S, Berwouts D et al (2013) Hypofractionated whole breast irradiation for patients with large breasts: a randomized trial comparing prone and supine positions. Radiother Oncol 108:203–208
24. Veldeman L, Schiettecatte K, De Sutter C, Monten C, van Greveling A, Berkovic P et al (2016) The 2-year cosmetic outcome of a randomized trial comparing prone and supine whole-breast irradiation in large-breasted women. Int J Radiat Oncol Biol Phys 95:1210–1217
25. Veldeman L, Speleers B, Bakker M, Jacobs F, Coghe M, De Gersem W et al (2010) Preliminary results on setup precision of prone-lateral patient positioning for whole breast irradiation. Int J Radiat Oncol Biol Phys 78:111–118
26. Boute B, De Neve W, Speleers B, Van Greveling A, Monten C, Van Hoof T et al (2017) Potential benefits of crawl position for prone radiation therapy in breast cancer. J Appl Clin Med Phys 18:200–205
27. Mulla Z, Iskanderani O, Weber A, AlMohamad A, Al-Amoodi MS, Soaida S (2021) Comparing accuracy of thermoplastic mask versus commercial bra for the immobilization of pendulous breast during radiation therapy treatment: a retrospective cohort study. Adv Radiat Oncol 6:100592
28. Agostinelli SGS, Bellini A, Pupillo F, Guenzi M, Bosetti D, Blandino G, Taccini G (2015) Helical Tomotherapy of the breast: can thermoplastic immobilization improve the reproducibility of the treatment setup and the accuracy of the delivered dose? Phys Med 31:49–53
29. Cheng KF, Wu VW (2014) Comparison of the effectiveness of different immobilization systems in different body regions using daily megavoltage CT in helical tomotherapy. Br J Radiol 87:20130494
30. Rudat V, Nour A, Ghaida SA, Alaradi A (2016) Impact of hypofractionation and tangential beam IMRT on the acute skin reaction in adjuvant breast cancer radiotherapy. Radiat Oncol 11:100
31. Murray Brunt A, Wheatley DA, Arnold J, Somaiah N, Kelly S, Harnett A et al (2016) Acute skin toxicity associated with a 1-week schedule of whole breast radiotherapy compared with a standard 3-week regimen delivered in the UK FAST-Forward Trial. Radiother Oncol 120:114–118