Technical Innovations & Patient Support in Radiation Oncology 35 (2025) 100318

Contents lists available at ScienceDirect

Technical Innovations & Patient Support in Radiation Oncology

journal homepage: www.sciencedirect.com/journal/technical-innovations-and-patient-support-in-radiation-oncology

Validation of a weekly imaging protocol for tangential whole breast radiation therapy with a tattoo-less surface-guided setup

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ARTICLE INFO

Keywords:
SGRT
Patient positioning
Tattoo-less setup
Breast radiation therapy
Weekly imaging

ABSTRACT

This study explored whether tattoo-less surface guided setups with a first 4 fractions then weekly imaging schedule (F1-4&W) is a suitable alternative to tattoo alignment setups for adjuvant whole breast radiotherapy (WBRT) patients.

The daily CBCT images (n = 450) of 30 patients treated using tattoo-less surface-guided radiation therapy (SGRT) were retrospectively re-matched to a WBRT protocol. The accuracy of the re-match was assessed, and a F1-4&W imaging schedule applied to investigate the percentage of fractions that would have been treated to a 0.5 cm tolerance. The results were compared with the setup accuracy of 100 consecutive patients treated with WBRT using the existing practice of tattoo-based alignment.

95.8 % of the tattoo-less SGRT setup fractions were assessed to be treated within tolerance, with a maximum discrepancy from isocentre of 0.7 cm for a non-imaged fraction. When comparing imaged fractions, 98 % of these patients positioned within 0.5 cm of isocentre, while the tattoo-alignment method achieved this only 80 % of the time. The overall imaging frequency rates per patient were 51 % and 53 % for study (SGRT/CBCT) and control groups (EPI/tattoos) respectively.

We conclude that tattoo-less SGRT provides a consistently accurate method to setup supine tangential WBRT patients with a benefit to patient experience. Furthermore, a F1-4&W imaging schedule is sufficient to ensure patients are treated within tolerance, while maintaining appropriate indication for when increased imaging frequency is necessary.

Introduction

Standard practice for patient positioning in external beam radiation therapy has been to align permanent tattoo marks to setup lasers. However, advancements in technology and increased awareness of patient survivorship well-being are enabling a transition towards less invasive methods [1–6]. Surface-guide radiation therapy (SGRT) is a non-invasive patient positioning alternative that is rapidly increasing in use [1,2,6]. SGRT utilises multiple non-ionising light projection and camera systems which locate and track patient positioning in real time. In contrast to the 3 pinpoint locations of tattoos, SGRT provides a 'surface' of thousands of points triangulated off the patient resulting in increased accuracy, while also reducing positioning and kV image-matching times [7–11]. Furthermore, by eliminating an invasive tattoo procedure and the reminders of diagnosis and treatment, the use of SGRT can improve patients' body image and psychosocial health [3,4,12–14]. Supine breast radiation therapy patients at our institution who have daily cone-beam computer tomography (CBCT) imaging verification have been positioned using a tattoo-less SGRT technique since January 2023. The move from tattoo alignment setups to tattoo-less SGRT was actioned primarily to eliminate the need for permanent skin marks; as well as secondary benefits of reduced infection control risk, removal of an invasive procedure, and improved efficiency [6,7,9]. The only cohort of supine breast radiotherapy patients who did not transition to tattoo-less setups are those who do not have a daily CBCT image: whole breast radiation therapy (WBRT) (inclusive of post-mastectomy) patients planned with a tangential intensity modulated radiation therapy (IMRT) field arrangement. Unlike breast cases with a simultaneous integrated boost (SIB) or additional nodal treatment, due to the largely external and visible nature of the whole breast, the target

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https://doi.org/10.1016/j.tipsro.2025.100318
Received 26 March 2025; Received in revised form 14 May 2025; Accepted 3 June 2025
Available online 13 June 2025

position verification for WBRT does not require complex soft tissue matching Fig. 1. Therefore, a weekly imaging schedule with electronic portal imaging (EPI) and a positioning method of tattoo alignment to lasers followed by a manual match to the field central axis at the treatment field angle, as measured from the planning system and marked onto the patient, was retained. While a move from EPI to CBCT was desirable for improved precision and dimensionality [15,16] there was reluctance to move from weekly to daily imaging as the optimal timing and frequency of CBCT had not yet been established [17]. Furthermore, previous experience demonstrated that a 3-point tattoo setup alone was not consistently accurate enough for a weekly CBCT imaging protocol. Overall, the addition of manual matching to the CBCT was too cumbersome to make this clinically feasible.

This retrospective study was conducted to explore whether tattoo-less SGRT setups could reproduce the patient position with sufficient accuracy to be utilised for tangential WBRT whilst maintaining a weekly CBCT imaging protocol.

Methods

Equipment

All imaging was conducted using CBCT or EPI on an Elekta Synergy or Elekta Versa HD and matched on XVI v5.0.7.1 (XVI, Elekta Solutions AB, Stockholm, Sweden). The SGRT system used is C-RAD's Catalyst HD+, and patient course and delivery technique information was derived from the Mosaiq 2.83 Oncology Information System (OIS).

Selection criteria and study groups

Data from 100 consecutive patients previously treated at our institution with tattoo-aligned and manual field-matched WBRT using forward or inversely planned techniques was retrospectively used for the control group. These patients had been positioned supine and received 3 tattoos for positioning: one anteriorly and one on either side laterally at mid-breast level. For field matching, the central axis position for each tangent angle in relation to patient skin marks (tattoos) were measured on the planning system and marked on the patient with a temporary marker. Once the patients had been positioned by aligning tattoos to the room lasers, the central axis position at each tangent angle was assessed and the couch and the gantry manually adjusted within acceptable tolerances (≤0.5 cm and ± 3 degrees) to match the temporary marker for both angles.

The study group consisted of the first 30 supine breast patients positioned using a tattoo-less SGRT technique and daily CBCT imaging. This included patients who had been treated to the breast or chest wall, with or without SIB and/or regional nodal irradiation. These patients' CBCT images were re-matched offline for all fractions focusing solely on the chest wall, skin surface and soft tissue of the breast area to simulate an accurate tattoo-less WBRT match.

Both cohorts included free-breathing and deep inspiration breath-hold (DIBH) patients, and all patients were treated with a prescription of 40.05 Gy in 15 fractions to ICRU reference point, over three weeks using an IMRT technique.

Imaging protocols

For the control group, imaging had been conducted on fractions 1–3 and then weekly (fractions 8 and 13) using an EPI taken at either the medial or lateral tangent field angle. Initial images were taken daily until 3 consecutive images showed shifts to isocentre that were within tolerance (≤0.5 cm). If a weekly image was out of tolerance (OOT), images were taken for subsequent fractions until 2 consecutive fractions were within tolerance. A localisation trend review (LTR) was applied after the first 3 fractions to account for systematic setup variations. This involved the average of the shifts to isocentre from the past 3 image matches being applied to the planned couch shifts to isocentre from the treatment reference point.

Tattoo-less SGRT setups eliminate planned couch shifts to isocentre, therefore an LTR cannot be performed in the traditional way. Instead, a new patient surface position reference is acquired on fraction 1 after the patient position has been corrected to match the planned isocentre, using a CBCT match. This position reference is then used to setup to for subsequent fractions. The imaging schedule thereafter is CBCT on fractions 2 to 4, then fractions 8 and 13 (F1-4&W). Imaging on fractions 2 to 4 help verify that the patient setup position stays within tolerance using the new position reference, and to determine whether the shifts on fraction 1 are random or systematic. Where the discrepancy from isocentre is OOT, a new position reference is captured after CBCT shifts have been actioned for any fraction. As per the incumbent protocol, initial images are taken daily until 3 consecutive images are within tolerance. Should a weekly image be OOT, subsequent fractions are imaged until 2 consecutive fractions are within tolerance. All images for both cohorts were taken and actioned pre-treatment delivery. Our study analysed 1500 fractions for the control group, of which 785 fractions were imaged, and 450 fractions for the study group, of which all were imaged but then differentiated as imaged (n = 231) or non-imaged (n = 219) fractions as per the study protocol.

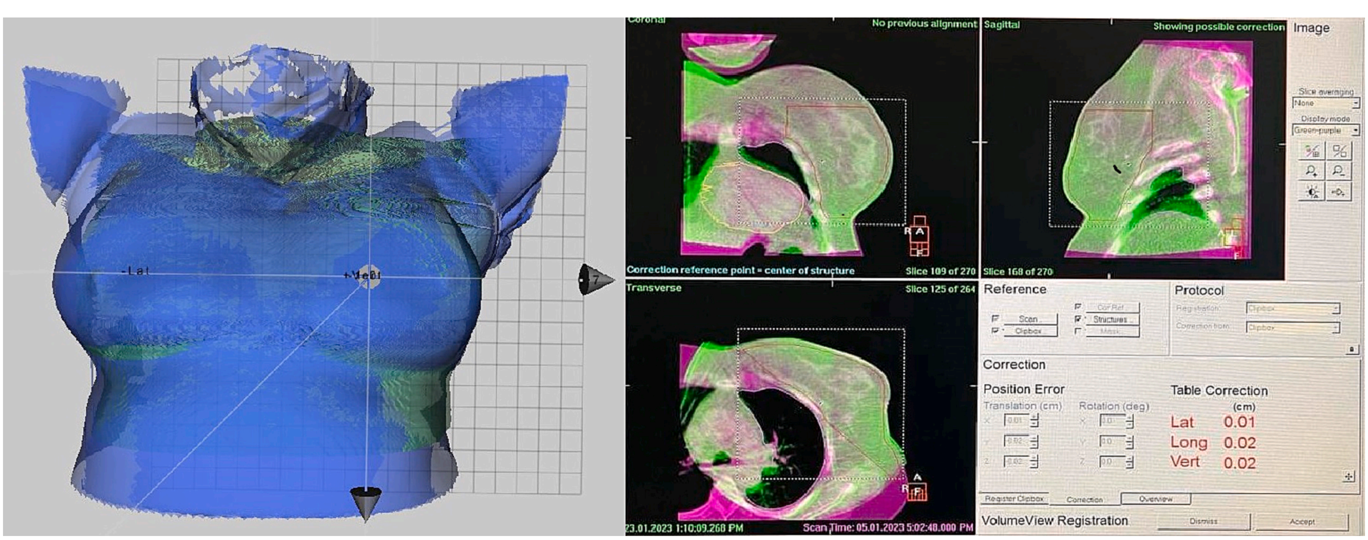

Fig. 1. Matching a planned and live surface position reference with Catalyst HD+ (left) and the CBCT match of a tattoo-less breast only case on XVI (right).

Table 1
Study group imaging protocol.

Standard imaging protocol

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Example of schedule with additional imaging required (1)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Example of schedule with additional imaging required (2)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

	Fraction with CBCT imaging + new reference capture
	Fraction with CBCT imaging: shifts within tolerance (<5mm)
	Fraction with CBCT imaging: shifts out of tolerance (≥5mm) + new reference capture
	Additional fraction with CBCT imaging scheduled to confirm new reference
To proceed with a non-imaged fraction: 3x **initial** consecutive approved images required (e.g. fractions 2-4) 2x consecutive approved images required **following a weekly image out of tolerance** (e.g. fractions 9-10)	

Investigation methods

For the study group, the residual discrepancies from isocentre in the vertical, lateral, and longitudinal directions were recorded for the breast-only CBCT match for each fraction. To simulate setting up to a new SGRT (Catalyst) position reference from fraction 2, the CBCT shift values from fraction 1 were subtracted from all subsequent fraction matches for each direction. If any subsequent fractions had a value OOT on a F1-4&W imaging fraction, these shifts were subtracted from all subsequent fractions, to simulate the recapturing of a new Catalyst position reference. Imaged fractions were designated as fractions 1–4, 8 and 13, as well as 2–3 fractions following a fraction where a new Catalyst position reference would have been captured. All other fractions were designated as "non-imaged" fractions. No action was taken for OOT results on non-imaged fractions as they would not have been seen in a clinical setting. The rate of non-imaged fractions that were OOT, the magnitude of these discrepancies and the magnitude of discrepancies from isocentre for all tattoo-less breast-only setup fractions were recorded. It should be noted that when setting up patients using SGRT, they were positioned to be within one degree for rotations and within 1 mm translationally of the planned reference surface for optimal alignment accuracy.

The setup OOT rate from the control group were taken from the EPI records for each patient in the Mosaiq OIS. These consisted of an approved or rejected status manually entered by the radiotherapy staff after matching on set; and not specific measurements of discrepancies from isocenter in a particular direction.

Statistical analysis

Image rejection rates for each cohort were compared with a *t*-test and Mann Whitney *U* test methods. Rejection rates for all fractions, and all *imaged* fractions, were determined and compared to the baseline cohort rates. Cumulative probabilities as a function of magnitudes of failure under proposed protocol were determined.

Results

Accuracy of tattoo-less SGRT setups

The frequency distributions of the discrepancies from isocentre for all tattoo-less fractions (n = 450) were normal and centred around zero, except for results in the vertical plane (see Fig. 2 i-iii). The mean and standard deviations of the discrepancies in each direction were: −0.01 cm (longitudinal, SD = 0.25 cm); −0.02 cm (lateral, SD = 0.21 cm); and 0.04 cm (vertical, SD = 0.23 cm). The maximum discrepancy observed across all fractions was 1.0 cm.

Missed out-of-tolerance results

The simulation study indicated 19 of 450 total fractions would have positions OOT missed under the proposed protocol. This equates to 4.2 % of all fractions (8.2 % of the non-imaged fractions), therefore 95.8 % of total fractions would be treated in tolerance under the protocol. The magnitude of discrepancies for the 19 missed fractions were 0.5 cm (n = 7), 0.6 cm (n = 9), and 0.7 cm (n = 3). Therefore, the maximum discrepancy missed was 0.2 cm OOT. Had new reference position corrections not been applied to the values, 30 of 450 total fractions would have been treated OOT. This would have equated to 6.7 % of all fractions (13.7 % of non-imaged fractions), therefore 93.3 % of total fractions would be treated within tolerance.

For the control group (n = 785), 80 % of the imaged fractions were within tolerance (see Table 2).

Imaging frequency

Nominally, the control group (EPI/tattoos) would have imaging on 5 of 15 fractions (33 %) and the study (SGRT/CBCT) group would involve imaging on 6 of 15 fractions (40 %). The actual rates of imaging, due to OOT matches, was 53 % in the control group and 51 % in the study group.

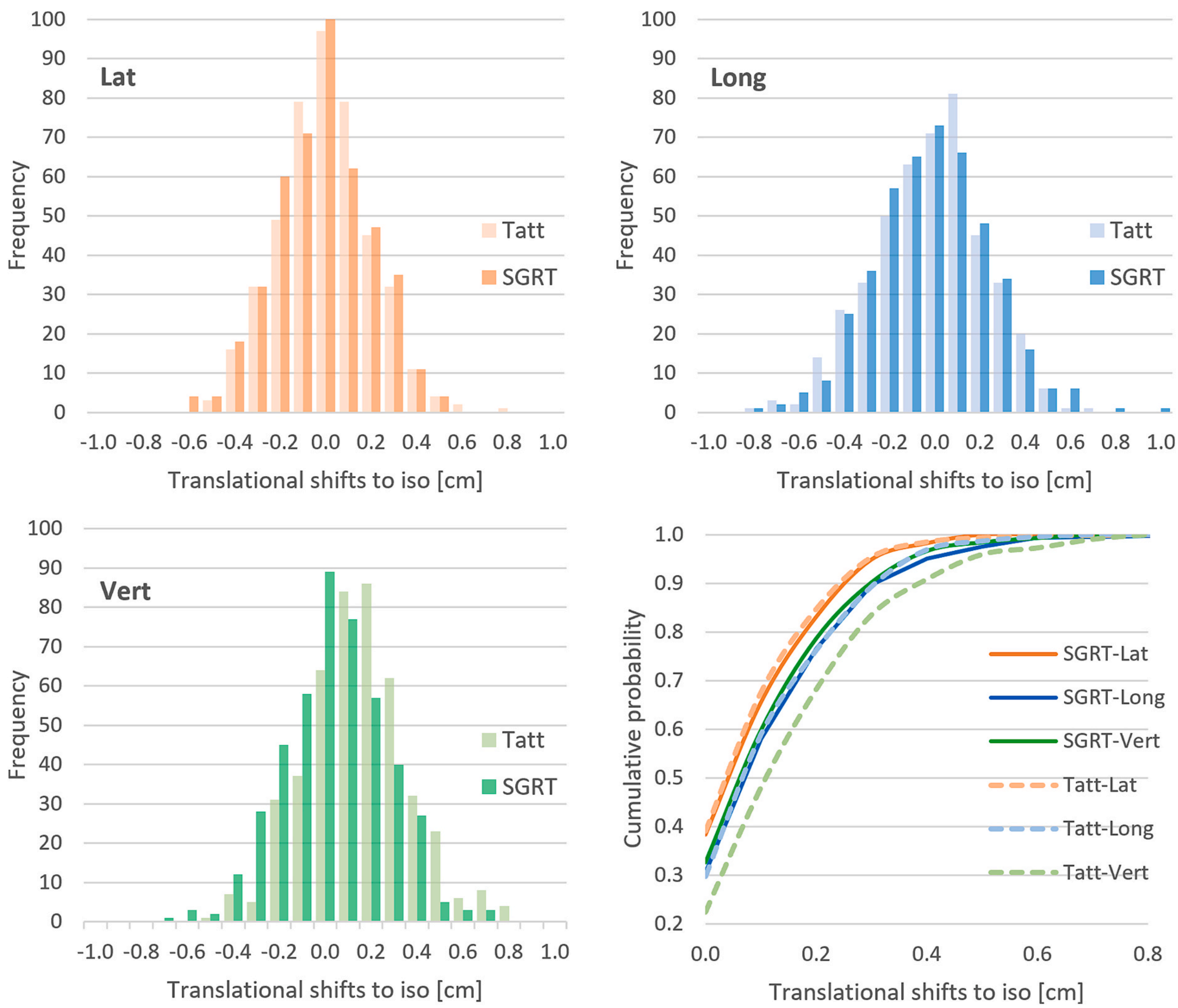

Fig. 2. (i-iv): Frequency distributions of the displacement from isocentre of the tattoo less-SGRT imaging protocol without position reference captures (i-iii, grey), and with position reference capture introduced for imaged fractions, with an out of tolerance result (i-iii, blue). The cumulative probability of the displacements from iso for each is shown (iv). The dashed lines represent the minimum probability from the with and without position reference capturing. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2
Comparison of probabilities for in tolerance results from tattoo-based and proposed tattoo-less SGRT-imaging protocols (imaged fractions only).

Discrepancy for imaged fractions only	Tattoo's + LTRs	Tattoo-less	Tattoo-less with position reference captures
≤0.3 cm	–	84 %	90 %
≤0.4 cm	–	91 %	95 %
≤0.5 cm	80 %	96 %	98 %
≤0.6 cm	–	97 %	99 %
≤1.0 cm	–	100 %	100 %

Rejection rates for imaged only fractions

The mean and median rejection rate of the proposed SGRT imaging protocol was less than that of the control group protocol. However, the difference across the patient courses tested was not statistically significant. See Table 3.

Discussion

The results of this study show that a high degree of accuracy can be achieved from the combination of tattoo-less surface-guided setup and F1-4&W CBCT imaging for tangential breast radiation therapy. Given the much lower rate of OOT imaged fractions, it is reasonable to conclude that it is a more accurate method compared to the current practice of a tattoo-alignment setup with a F1-3&W EPI schedule. One consideration which further supports the argument for tattoo-less setups is the difference in imaging modalities between the two cohorts. The baseline cohort patients had electronic portal imaging (EPI) at the tangent angle, whereas all tattoo-less patients had CBCT imaging. CBCT

Table 3
Comparison of rejection rates in each imaging protocol.

	DRR/Tattoo	SGRT/Tattoo-less
n	100	30
Shapiro-Wilk	<0.001	<0.001
Mean ± SD	19.9 % ± 23.6 %	11.3 % ± 12.1 %
Median	13.5 %	13.0 %
Mann Whitney *U* test		
H_0	$Group_1 = Group_2$	
p-value	0.212	
Result	H_0 cannot be rejected: the difference between the randomly selected value of Tattoos and the SGRT populations is **not** big enough to be statistically significant	

provides lateral positioning details that aren't apparent with EPI matching [15,16]. Published data has demonstrated that while there may be potential downsides of CBCT use such as integral dose, EPIs can underestimate the actual bony anatomy setup error by 20–50 % for breast patients, and that use of CBCT decreased setup uncertainties significantly [15,16]. Based on this rationale and given that CBCT is used for all daily imaged breast patients at our institution for an accurate soft tissue match, the move to a F1-4&W imaging schedule was conducted stipulating CBCT as the imaging modality. The results of this study have shown that we are able to keep the imaging schedule non-daily for this treatment technique, allowing minimisation of dose to the patient while being confident in positioning accuracy. A limitation of this study is that under previous departmental EPI matching protocols, a discrepancy of 0.5 cm could have been determined as either within or out of tolerance depending on staff discretion. As the only consistently entered data was whether the image was approved or rejected, and not the magnitudes of the shifts made, this uncertainty was unable to be fully characterised. For tattoo-less patients a discrepancy from isocentre of 0.5 cm or more has been marked as out of tolerance for all cases. Another point for consideration is that this study has been simulated to replicate breast-only matches, with new position reference captures applied retrospectively to re-matched data. As such, there is the potential for results to differ in clinical practice, but discrepancies are expected to be minimal.

The frequency distribution and cumulative probability data showed that without Catalyst position reference recaptures, discrepancies from isocentre in the vertical direction present the most probability of causing an out of tolerance result. This was improved with position reference capturing. Interestingly, with position reference capturing applied, discrepancies in the long direction were the cause of residual out of tolerance results. Further, position reference capturing degraded the aggregate results for the lateral direction. However, in general, position reference capturing reduced the probability of an out of tolerance result. Overall, the likelihood of an out of tolerance result is greatly reduced from either tattoo-less protocol with respect to the tattooed protocol.

The Mann-Whitney U test is robust but may have limitations especially given the highly skewed discrete (Poisson) distribution of the reject rate un-paired population data. Despite the result not achieving statistical significance, there is a clear effect in favour of the proposed SGRT protocol, which given the various other identified benefits does not pose any shortcomings in terms of the reject rate vs the incumbent protocol.

Table 1 shows tattoo-less SGRT setups with position reference captures gives consistently higher rates of in-tolerance results at any magnitude of discrepancy from isocentre for imaged fractions, and these results can be seen represented by the dashed lines in the Fig. 2. iv cumulative probability chart.

Conclusion

The results support the treatment of supine breast-only patients within tolerance (<0.5 cm from isocentre in all directions) with a tattoo-less SGRT setup and F1-4&W CBCT protocol at an accuracy rate of 96 %. Where a fraction match was out of tolerance, the largest magnitude from isocentre was 1 cm (1/450) and this was for an imaged fraction so would have been corrected pre-treatment. A comparison of the rejection rates of imaged fractions with the control cohort show 98 % of imaged fractions would be within tolerance compared to 80 % for the control cohort, which is current practice. While the minimum imaging rate for F1-4&W is 40 % per patient compared to 33 % for the control cohort, actual imaging rates from the study were 51 % for F1-4&W compared to 53 % for the baseline cohort, showing very comparable actual imaging rates. In line with this, rejection rate comparisons for imaged fractions showed that although statistically insignificant, the tattoo-less SGRT setup cohort had lower average rejection rates per patient. Thus, the recommendation derived from this study is that tattoo-less SGRT setups for tangential WBRT with a F1-4&W CBCT protocol is a feasible alternative to a tattoo and field alignment setup. Further, this study demonstrated that the SGRT setup accuracy is such that daily imaging is not routinely required for this patient cohort to be treated within a 0.5 cm tolerance, and that a F1-4&W CBCT schedule is sufficient to identify when extra imaging is required. This would streamline the positioning workflow and remove the need for tattoos for all supine breast patients at our institution.

Authorship statement

All authors contributed to the study conception and design. Project administration was conducted by Sumie Namba and Matthew Hoffman. Data collection and analysis were performed by Sumie Namba, Jared Steel, Hannah Thompson and Abbey Baylis. The first draft of the manuscript was written by Sumie Namba and Jared Steel. All authors reviewed and approved the final manuscript. Supervision was provided by Matthew Hoffman and Dr Thomas Shakespeare.

Data availability statement

The deidentified data that support the findings of this study are available from the corresponding author, upon reasonable request.

Ethics approval statement

The submission has been reviewed, and it has been judged that the project is exempt from the requirement for ethical and scientific review by a Human Research Ethics Committee (HREC) in accordance with section 5.1.22. of the National statement on Ethical Conduct in Human research (2007).

Funding statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Special thanks to Regina Stephen, Sarah Edwards, Jacqueline Pacey, Ashley Rankin and MNCCI staff for their expertise and support in this project.

References

[1] Batista V, Gober M, Moura F, et al. Surface guided radiation therapy: an international survey on current clinical practice. Technical Innovations Patient Support Radiat Oncol 2022;22:1–8. https://doi.org/10.1016/j.tipsro.2022.03.003.

[2] Al-Hallaq HA, Cerviño L, Gutierrez AN, et al. AAPM task group report 302: Surface-guided radiotherapy. Med Phys 2022;49. https://doi.org/10.1002/mp.15532.

[3] Probst H, Dodwell D, Gray JC, et al. An evaluation of the accuracy of semi-permanent skin marks for breast cancer irradiation. Radiography 2006;12:186–8. https://doi.org/10.1016/j.radi.2005.07.001.

[4] Landeg SJ, Kirby AM, Lee SF, et al. A randomized control trial evaluating fluorescent ink versus dark ink tattoos for breast radiotherapy. Br J Radiol 2016;89:20160288. https://doi.org/10.1259/bjr.20160288.

[5] Wurstbauer K, Sedlmayer F, Kogelnik HD. Skin markings in external radiotherapy by temporary tattooing with henna: Improvement of accuracy and increased patient comfort. Int J Radiation Oncology*Biology*Physics 2001;50:179–81. https://doi.org/10.1016/S0360-3016(01)01439-0.

[6] Naidoo W, Leech M. Feasibility of surface guided radiotherapy for patient positioning in breast radiotherapy versus conventional tattoo-based setups- a systematic review. Tech Innovations Patient Support Radiation Oncol 2022;22:39–49. https://doi.org/10.1016/j.tipsro.2022.03.001.

[7] Jimenez RB, Batin E, Giantsoudi D, et al. Tattoo free setup for partial breast irradiation: a feasibility study. J Appl Clin Med Phys 2019;20:45–50. https://doi.org/10.1002/acm2.12557.

[8] Kügele M, Mannerberg A, Nørring Bekke S, et al. Surface guided radiotherapy (SGRT) improves breast cancer patient setup accuracy. J Appl Clin Med Phys 2019; 20:61–8. https://doi.org/10.1002/acm2.12700.

[9] Rigley J, Robertson P, Scattergood L. Radiotherapy without tattoos: could this work? Radiography 2020;26:288–93. https://doi.org/10.1016/j.radi.2020.02.008.

[10] Giantsoudi D, Lalonde A, Barra C, et al. Tattoo-free setup for patients with breast cancer receiving regional nodal irradiation. Pract Radiat Oncol 2023;13:e20–7. https://doi.org/10.1016/j.prro.2022.08.001.

[11] Stanley DN, Stanley D, McConnell K, et al. Comparison of initial patient setup accuracy between surface imaging and three point localization: a retrospective analysis. J Appl Clin Med Phys 2017;18:58–61. https://doi.org/10.1002/acm2.12183.

[12] Moser T, Creed M, Walker R, et al. Radiotherapy tattoos: Women's skin as a carrier of personal memory—what do we cause by tattooing our patients? Breast Journal 2020;26:316–8. https://doi.org/10.1111/tbj.13591.

[13] Fingeret MC, Teo I, Epner DE. Managing body image difficulties of adult cancer patients: lessons from available research. Cancer 2014;120:633–41. https://doi.org/10.1002/cncr.28469.

[14] Lastrucci A, Marrazzo L, Meattini I, et al. Advancing patient setup: a comprehensive scoping review of tattoo-less techniques in radiation therapy. Crit Rev Oncol Hematol 2024. https://doi.org/10.1016/j.critrevonc.2024.104518.

[15] Topolnjak R, Fuller CD, Sonke J-J, et al. Breast patient setup error assessment: comparison of electronic portal image devices and cone-beam computed tomography matching results. Int J Radiat Oncol Biol Phys 2010;78:1235–43. https://doi.org/10.1016/j.ijrobp.2009.12.021.

[16] Jain P, Marchant T, Green M, et al. Inter-fraction motion and dosimetric consequences during breast intensity-modulated radiotherapy (IMRT). Radiother Oncol 2009;90:93–8. https://doi.org/10.1016/j.radonc.2008.10.010.

[17] Quinn A, Holloway LC, Begg J, et al. Kilovoltage cone-beam CT imaging dose during breast radiotherapy: a dose comparison between a left and right breast setup. Med Dosim 2014;39:190–3. https://doi.org/10.1016/j.meddos.2013.12.009.