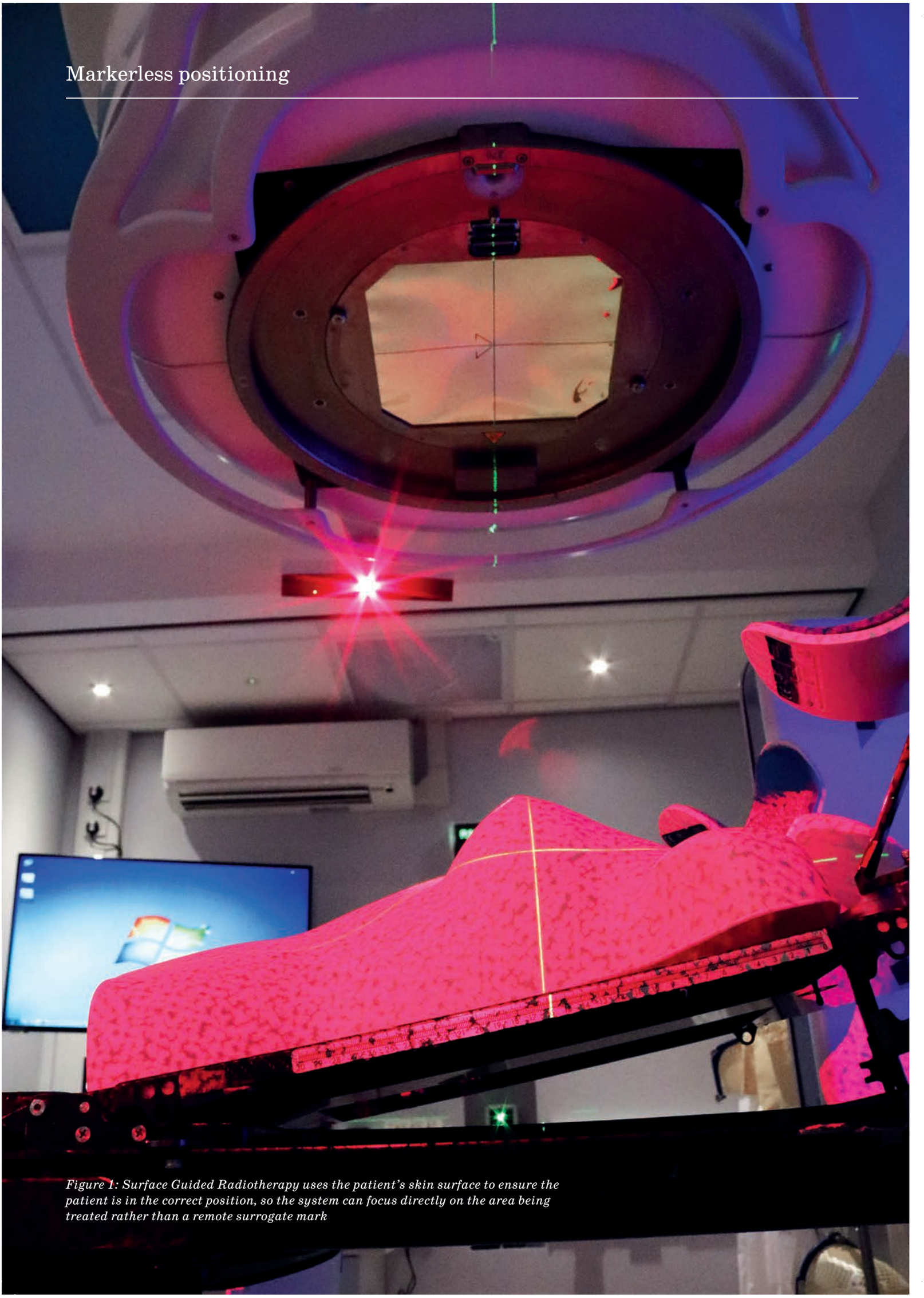


Figure 1: Surface Guided Radiotherapy uses the patient's skin surface to ensure the patient is in the correct position, so the system can focus directly on the area being treated rather than a remote surrogate mark

A new technology is improving accuracy for breast radiotherapy

Markerless radiotherapy positioning

Ben Allen, Mark Ramtohul

The current standard for positioning breast patients in radiotherapy is to use subcutaneous permanent tattoo marks as a surrogate reference point. Although the permanent nature of the tattoos helps to achieve a reproducible position and provides historical marks should the patient need more treatment, they have their own inherent issues.

The tattoos are under the skin, which is a mobile, elastic organ[1] and, because they are a surrogate, they are often not where we want to treat. A stable point on the patient's skin is picked to place the tattoo as close to the area being treated as possible but compromises are often made. When the patient starts radiotherapy, a shift is applied to move from the tattoo to the area we need to treat. This is often a manual shift of up to 10cm and can lead to a baseline inaccuracy in radiotherapy set-ups.

The use of permanent marks changes a patient's appearance cosmetically. The marks can cause psychological distress and act as a permanent reminder of a patient's cancer treatment and can exacerbate their feelings of lack of control. There are alternative temporary skin marks, such as henna ink or pen marks, that can be used instead of tattoo placement but these can fade or disappear and maintaining them throughout a treatment course can inhibit normal washing routines[1].

Tattoos have continued to be the international standard for positioning radiotherapy patients, largely due to the lack of alternative reliable methods. But with advancing technology, there are now means to position patients without marking their skin.

Surface Guided Radiotherapy (SGRT) is an expanding technology that is becoming increasingly popular due to the potential to provide markerless radiotherapy treatment as well as provide other associated benefits.

University Hospitals Birmingham, Queen Elizabeth Hospital uses SGRT for facilitating a deep inspiration breath hold (DIBH) technique for left-sided breast cancer treatment. Based on this SGRT experience, we decided to explore the potential of using SGRT to implement markerless radiotherapy positioning for breast cancer patients. As SGRT uses the patient's skin surface to ensure the patient is in the correct position, the system can focus directly on the area being treated rather than a remote surrogate mark, providing potential improvements in accuracy of patient positioning and overall treatment delivery (Figure 1).

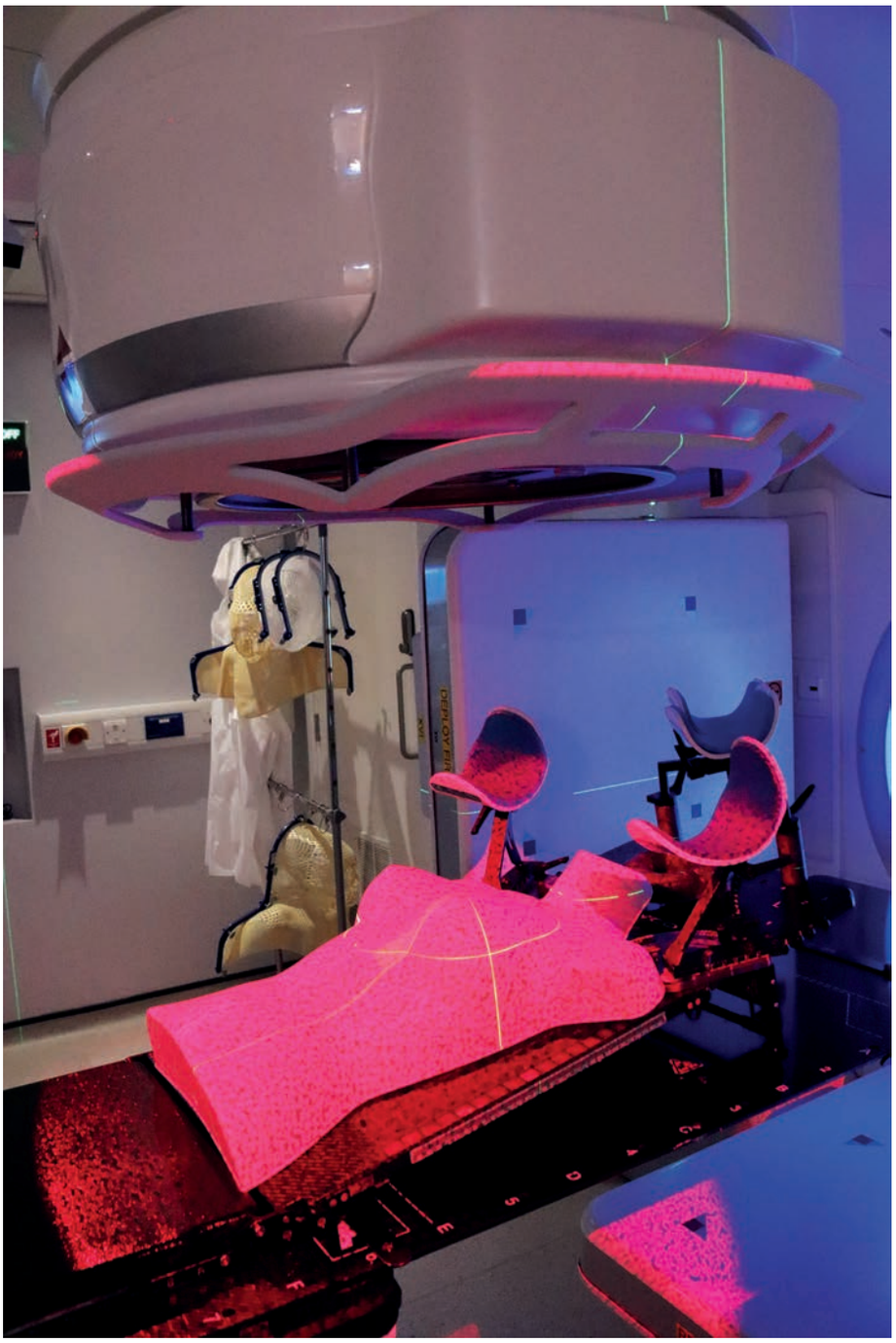
Literature review

Accuracy

Gaisberger et al[2] developed an in-house optical surface scanner. By performing daily surface scans of 14 breast radiotherapy patients and comparing to the Electronic Portal Imaging (EPI) results, they demonstrated good accordance between the two (-.05±0.94mm with a 95% confidence interval).

Although this technology and its implementation were developed in-house and are different to commercially available SGRT systems, the findings were supported by another study carried out by Stanley et al[3]. Cone Beam Computed Tomography (CBCT) imaging results of patients positioned with a traditional tattoo method were compared to the CBCT imaging results of patients positioned with a C-RAD Catalyst SGRT system. A statistically significant ($P<0.01$) reduction in the shift vectors for all the treatment sites positioned with SGRT was reported, including breast patients. The study included a large sample of patient fractions, between 600-900 fractions per site, per positioning method.

A comparison study by Rigley and Robertson[4] further supports these findings, in which 22 patients were positioned with a traditional tattoo method and 21 patients were positioned with SGRT alone. Based on the 3D vector magnitude, they concluded that a markerless technique with SGRT offers set-up accuracy comparable to a traditional tattoo method in right-sided breast cancer patients. For left-sided DIBH patients, SGRT positioning was favourable. This is to be expected due to›



Figures 2 and 3 (opposite page): All patients were positioned on a CIVCO MT-350 Breastboard and treated on Elekta Precise Linear Accelerators equipped with AlignRT

As well as potential accuracy improvements, tatooless radiotherapy has psychosocial benefits for breast cancer patients

the reduction of breathing motion.

Relying on tattoos can also be problematic when positioning patients with darker skin tones as they can often be difficult to find due to their small size and their dark blue colouring[5]. This is not restricted to darker skin tones because the tattoos can be confused with freckles or other marks on the patient's skin, leading to potential inaccuracies in treatment positioning and, therefore, delivery.

SGRT systems can also be used to monitor the patient in six degrees of freedom during treatment to minimise intrafractional motion and improve the accuracy of overall treatment delivery. Moncosu et al[6] concluded that translations and rotations can be accurately detected with surface monitoring systems. This would remove the subjectivity associated with radiographers monitoring any intrafractional motion by simply observing pen marks drawn on the patient's skin.

This study was based on phantom measurements but it is one of the main selling points of all commercially available SGRT systems in clinical use, particularly when treating DIBH patients.

Psychosocial

As well as potential accuracy improvements, there is also the psychosocial aspect of tattooless radiotherapy to be considered as a patient benefit. Some patients feel that permanent radiotherapy tattoos pose a 'significant psychosocial challenge for some women living with breast cancer'[7]. It is suggested that tattoos compound the problems for women dealing with cosmetic changes to their breasts and bodies arising from treatment. This is supported by Fingeret et al[8], who report that body image concerns affect a large number of breast cancer patients, with issues persisting into long-term survivorship.

The placement of permanent tattoos would only to serve to add to the body image concerns that patients have following surgery. Psychological issues, body image and tattoo removal are widely discussed on breast cancer forums, further highlighting the focus patients place on tattoos. However, the negative aspects of permanent tattoos may feature heavily on forums due to the fact that people who feel strongly about tattoos are more likely to openly discuss these feelings[9]. People who do not have concerns about their tattoos may go unheard. Indeed, some patients and healthcare practitioners see permanent tattoos as a minor issue, based on the fact that they are needed for often lifesaving treatment.

Radley and Bell[10] describe women who have redefined the experiences of breast cancer by having decorative tattoos made to incorporate their medical tattoos, rather than seeing them negatively. On

Figure 3: for caption see page 12 opposite

EPI technique
Stereoscopic paired Megavoltage EPIs taken at the lateral oblique treatment angle and 0 degrees (see Figure 4).
Day 1 then weekly imaging schedule.
Mosaiq image registration – offline.
Action level for repeat EPID – 0.5cm.
If a systematic error of ⩾0.5cm is identified over two treatments, a correctional shift is applied.

balance, it is unlikely that any patient would choose to have a permanent tattoo if there was an alternative option.

Efficiency

SGRT set-up also has the potential to provide positioning efficiencies by reducing the steps in the set-up process. Zhao et al[11] reported that using an SGRT system significantly reduced set-up and overall treatment times. Anecdotally, since the conclusion of the study being discussed, the radiotherapy department has seen a reduction in set-up time when using SGRT to position patients and more work will be done to document this further.

Summary

After reviewing the literature available, the evidence suggests that SGRT has the potential to improve treatment accuracy through initial patient positioning as well as by monitoring the patient during treatment, to provide positioning and treatment efficiencies and to have a positive impact on the psycho-social well-being of patients.

Method

The SGRT positioning technique needs to be evaluated against the traditional tattoo positioning technique within the department to ensure that a change to SGRT markerless positioning can be safely implemented. It will also determine whether local adoption of markerless positioning, combined with the department's local protocols, will demonstrate previously reported improved accuracy. Review of the EPI results will determine which positioning technique results in fewer systematic corrections introduced into the patient positioning process.

Retrospective collection of EPI results of all SGRT DIBH breast-only patients treated between June 2018 and December 2018 (n = 95) was carried out. Retrospective collection of EPI results of free-breathing (FB) breast-only patients positioned with the traditional tattoo technique was also carried out (n=96). A search was performed on the Mosaiq Record and Verify system to identify any breast-only radiotherapy patients positioned with tattoo technique in the past three months and the first 96 patients were selected, to keep the sample size the same.

Based on all current SGRT-positioned patients' EPI results being in DIBH, the resulting lack of breathing motion would lead to an unfair comparison, so a third group was needed to ensure a direct comparison. This required a prospective selection of FB patients to be positioned with SGRT and EPI results to be collected.

The technical lead radiographer selected the patients for SGRT positioning and indicated on the patient's treatment schedule. They did not know the patients and had not read their notes. Patient selection was limited to a certain number of SGRT-positioned patients each week to maintain safety on the treatment unit. The patients were still given tattoos in case we needed to revert back to the traditional positioning technique but the tattoos were not used by the treatment radiographers. AlignRT SGRT system by VisionRT was used solely for patient positioning. It will not be possible to collect any tattoo-positioned DIBH results because SGRT is the only way that DIBH is facilitated in the department. All patients were positioned on a CIVCO MT-350 Breastboard and treated on Elekta Precise Linear Accelerators equipped with AlignRT. >

Figure 4: Stereoscopic paired Megavoltage EPIs taken at the lateral oblique treatment angle and 0 degrees

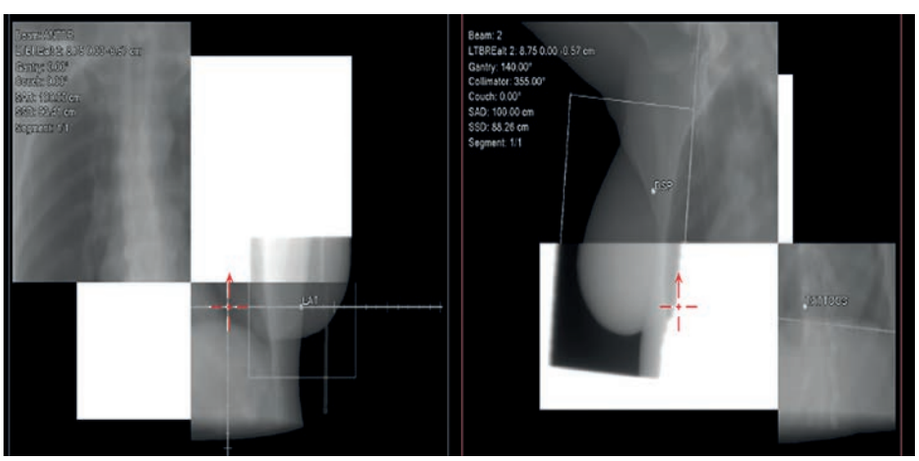


Table 1: results

The percentage of patients requiring correctional shifts due to systematic error for SGRT DIBH, SGRT FB and tattoo FB are 4.2%, 5.4% and 28.1% respectively.
The percentage of patients requiring a repeat EPI due to random error for SGRT DIBH, SGRT FB and tattoo FB are 10.5%, 23% and 21.9% respectively.
The maximum number of repeat images due to random error for SGRT DIBH, SGRT FB and tattoo FB were one, three and six respectively.
Using the Fisher exact test, the probability that the accuracy of each technique is the same is $p<0.0001$.
No patients had to revert back to a tattoo-based positioning technique.

Conclusion

The results suggest that SGRT positioning produces a more consistent and reproducible treatment position for both DIBH and FB breast patients compared with a tattoo positioning technique. The SGRT DIBH positioning required less positional intervention due to reduced systematic error, mainly because breathing motion is eliminated through breath hold.

However, there is still a marked reduction in systematic error when comparing SGRT FB positioning with tattoo FB positioning, with 5.4% of SGRT FB patients requiring a systematic correction compared with 28.1% of tattoo FB patients. This reduction in intervention results in reduced imaging dose for the patients as there are fewer verification images needed overall. It also means quicker treatment because there is an intrinsic increase in treatment duration on fractions requiring verification images.

When comparing random error between the two FB groups, there were very similar numbers of patients who demonstrated errors that resulted in the need for a repeat verification image. The DIBH group was lower but, again, this is likely to be due to the inhibited breathing motion during treatment and therefore image acquisition.

The maximum number of repeat images needed was lower for the SGRT FB group, suggesting a more consistent positioning technique. However, only the maximum number of repeat images was collected so this would need to be explored further.

Overall, the SGRT-positioned patients demonstrated less positional variation, suggesting that SGRT positioning is more accurate when compared with the traditional tattoo positioning technique when positioning breast radiotherapy patients. These results support the change to SGRT positioning for breast radiotherapy patients. This has enabled a markerless technique to be employed by the department, making it the first NHS site in England to make this change and provide patients with the associated benefits.

Limitations and future work

The study looked at 2D image verification. CBCT verification would give us more data.

The study looked at breast-only patients. However, as patient positioning is identical across all of our breast patients, we have adopted SGRT markerless radiotherapy for all breasts due to the confidence we have in the system and the results we continue to see.

Exploring the use of SGRT in other treatment areas is ongoing. Open face-mask treatment is already in progress and the benefits to SABR patients will be investigated.

Local data has been gathered on the efficiency of set-up for breast patients with SGRT compared with tattoo positioning to maintain capacity within the department. The results showed a quicker set-up for SGRT patients. ■

The results enabled us to employ a markerless technique at the department, the first NHS site in England to make this change

About the authors

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References

References are available to view and download at www.sor.org/learning/library-publications/itp.

This article has been prepared following local guidance relating to the use of patient data and medical images. To comment on the article, please write to editorial@itpmagazine.co.uk.

HOW TO USE THIS ARTICLE FOR CPD

QA code: 9F9B718A

1. What are the main principles of SGRT?
2. Within your department, what advantages do you see in implementing this technology?
3. Are there any disadvantages you can identify?
4. List some treatment sites that could be positioned using SGRT and explore the reasons why it would be a benefit to that particular area.
5. SGRT has a role to play in Stereotactic Ablative Radiotherapy (SABR) treatments. Think about how SGRT could be utilised to improve SABR treatments.

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