Surface Guided Radiation Therapy Positioning versus Traditional Triangular Positioning

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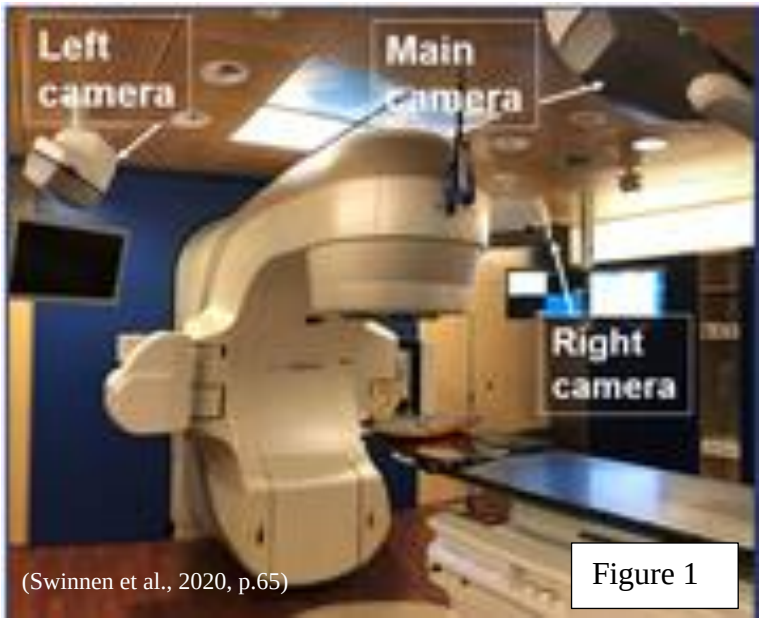
Introduction

Surface-guided Radiation Therapy (SGRT) is a positioning monitoring system utilizing 3D nonionizing optical surface imaging. This system assists in patient set-up and allows for real-time monitoring of the patient's skin surface during radiation therapy treatment. Surface-guided imaging, also known as optical surface monitoring (OSMS), can be used for many treatment sites such as breast, abdomen, head and neck, and extremities. SGRT is believed to have more advantages than the traditional triangular positioning including shorter set-up times, improved accuracy, reproducibility of treatment area, and improved patient comfort. Studies have also shown the planned dose delivery can also be monitored with SGRT and decrease dose to surrounding tissues.

How It Works

Surface-guided radiotherapy is an optical video-based (laser scanning) system that provides guidance for patient set-up as well as monitoring of the patient's surface during radiation treatment (Song et al., 2022). These non-invasive scanners in the treatment room comprise of three ceiling-mounted scanner cameras arranged approximately 120 degrees to each other (Swinnen et al., 2020). The configuration of the cameras can be seen in Figure 1. The scanners project a light pattern over the patient's surface and are reflected and captured by the cameras,



(Swinnen et al., 2020, p.65)

Figure 1

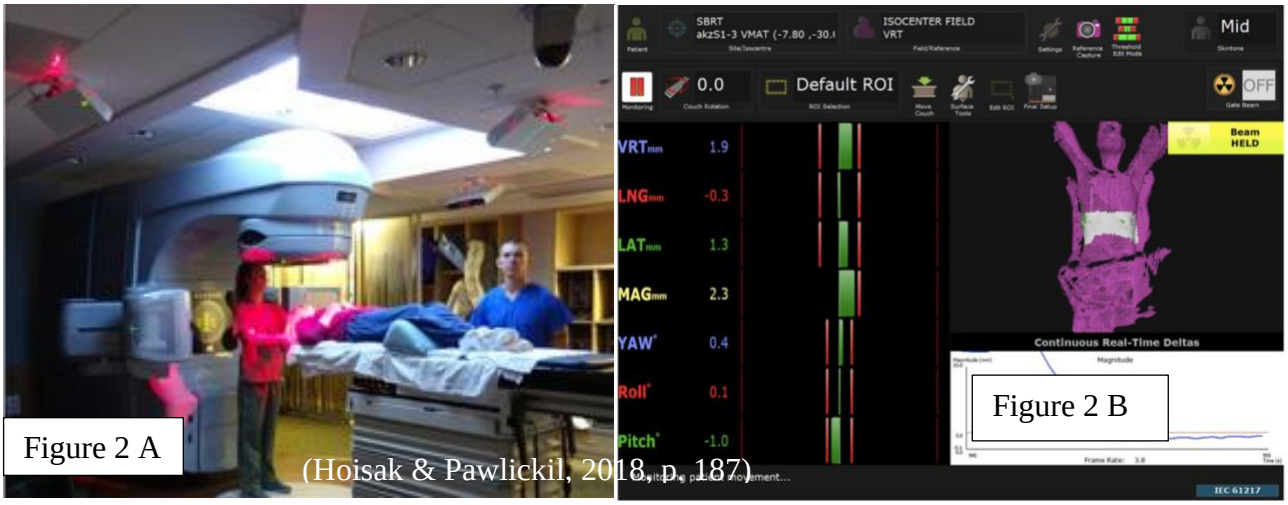


Figure 2 A

Figure 2 B

(Hoisak & Pawlickil, 2018, p. 187)

generating a three-dimensional reconstruction.

Figure 2A demonstrates the light pattern reflected onto the patient's surface. Figure 2B exhibits the three-dimensional reconstruction developed from the light reflections. "The reconstruction of the external surface of an object will be compared to a reference surface, which is in general based on the treatment planning CT-scan" (Dekker et al., 2021, p. 2). This skin light pattern then helps map the patient's skin contours in real-time to assist in treatment set-up. The three-dimensional reconstruction of the patient's surface represents "…six directions of movement:

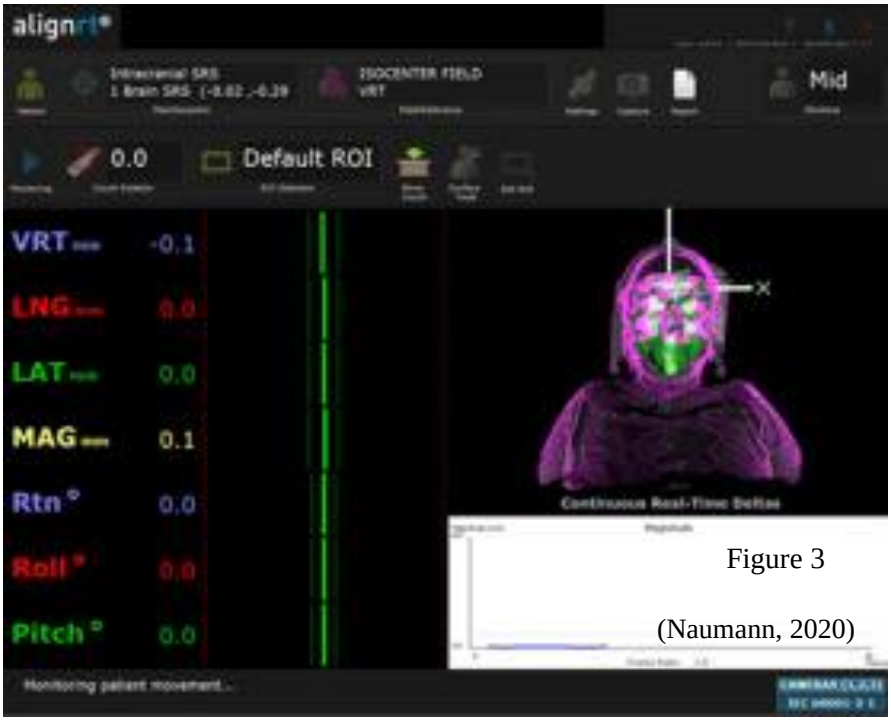
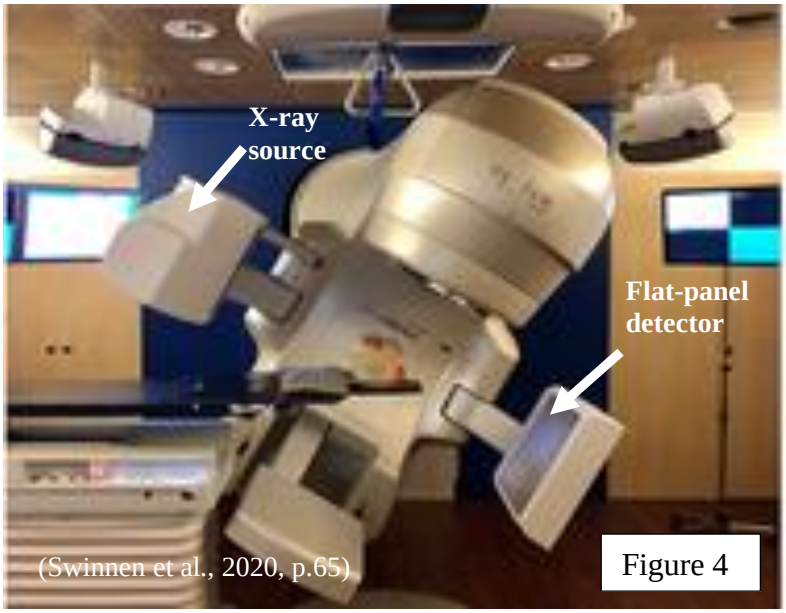


Figure 3

(Naumann, 2020)

vertical, longitudinal, lateral, pitch, roll, and yaw" (Washington et al., 2021, p. 423). The directional movements and thresholds can be seen in Figure 3. Issues can occur if the patient's skin is obscured, full visibility of the skin

surface is required to be successful. Once the radiation therapists are happy with positioning an image is obtained to verify positioning compared to the CT simulation of the internal anatomy. The imaging arms of the gantry, which obtains the x-ray image, is demonstrated in Figure 4.



(Swinnen et al., 2020, p.65)

Figure 4

Benefits/Advantages

Improved Accuracy/Better Reproducibility

SGRT can be used to improve patient setup accuracy and reproducibility. The continual monitoring for patient positioning reduces setup variability and positioning uncertainty, and improves accuracy (Nutt, 2023, p. 97). The live surface scanning can also be used to monitor the intra-fraction movements during treatment, "…if the movements exceed this predefined threshold, irradiation can be stopped" (Dekker, 2021, p. 1). Dose accuracy is improved when intra-fraction motion is minimized. Examples of intra-fraction motion are: "…patient movement on the couch, different orientations of the neck, shoulders or breast, and variations due to movement of internal organs, such as bladder and rectal filling, bowel movement or breathing motion" (Dekker, 2021, p. 1). SGRT can be beneficial for deep inspiration breath hold which is used with most breast cancer treatments to decrease the absorbed dose to the heart and lung. In the Radiation Therapist one study found that "…when assessing tangential breast treatments,

there was a 50% reduction in standard setup deviation when using SGRT technology" (Nutt, 2023, p. 98).

Decreased Dose

Another benefit of surface imaging is no additional radiation exposure. The use of the three-dimensional optical laser scanning over the patient's skin surface can determine variations in positioning and intra-fraction motion without the use of ionizing radiation (Nutt, 2023, p. 97). This can reduce the amount of image guided radiation therapy (IGRT) needed, "SGRT can be used to verify the accuracy patient shifts, thus decreasing patients' need for repeat imaging studies" (Nutt, 2023, p. 98). SGRT also provides the capability of beam interruption if movements exceed threshold, improving the accuracy of dose delivery. An example of live monitoring for treatment area can be seen in Figure 5. The red area represented on both the reconstruction and on the patient's surface represents movement outside the threshold.

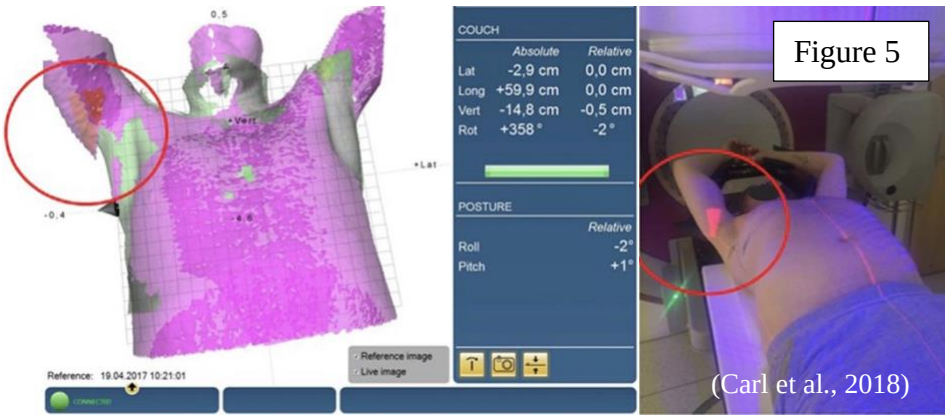


Figure 5

(Carl et al., 2018)

Improved Patient Comfort

Another advantage to SGRT is improved "….patient satisfaction and compliance with the overall experience of radiation therapy" (Nutt, 2023, p. 99). The ability to reconstruct a three-dimensional reconstruction of the patient's surface negates the need for tattoos. From personal experience, patient's do not like the tattoos and skin markings as it affects patients' emotional experience (Dekker, 2021, p. 2). In another study it was determined "..that tattoos from radiation

therapy serve as a psychological reminder of the cancer years after treatment" (Nutt, 2023, p. 98). Not only is there is no need for external markers, but there is also no need for immobilization masks. Immobilization masks are used during head and neck IMRT treatments, "the standard of care for patients undergoing head and neck IMRT typically involves the use of closed-face thermoplastic masks, which provide rigid constriction to ensure reproducible positioning…" and restricts movement (Nutt, 2023, p. 99). These masks can be uncomfortable for patients that are claustrophobic. Many patients reported discomfort with the masks, "the type of immobilization device used during treatment substantially affects a patient's reported level of pain and discomfort during radiation therapy, particularly for patients using a face immobilization mask" (Nutt, 2023, p. 99). SGRT requires full visualization of the patient's surface to form a three-dimensional reconstruction, thus needing the patient's face to be unobscured and free of the mask. Patient comfort can also be related to the length of time the patient is on the treatment table. In another study done in the Journal of Applied Clinical Medical Physics, SGRT "…appeared to provide faster and more accurate clinical procedures with improved patient safety" (Song et al., 2022).

Disadvantages

Surface guided radiotherapy has an advantage when it comes to a treatment area with a fixed tumor to surface correlation or an anatomical area located near the surface. A limitation with SGRT could occur "…when the target volume is located deeper in the body; it might not respond as robustly to movement along the patient's skin surface" (Nutt, 2023, p. 98). Another disadvantage to the surface guided system is the sensitivity with visibility of the light reflection. For instance, "…facial hair can lead to a decrease in light reflection, and consequently loss of information of the face visible to OST cameras" (Swinnen et al., 2020).

Traditional Triangular Positioning

The traditional triangular positioning consists of a three-point set of localization marks (generally tattoos) that are placed on the patient's skin surface that create an isocenter. The three points "…include both lateral sides and the medial aspect of the body" (Nutt, 2023, p. 97). The tattoos are then aligned using the room lasers and then followed IGRT imaging. IGRT imaging is used to verify patient alignment just as it is used after SGRT. The patient shifts and adjustments needed for treatment accuracy require repeat IGRT imaging to document the shifts are correct before radiation is emitted (Nutt, 2023, p. 97).

Another disadvantage to the triangular three-point localization is the inconvenience and integrity challenge of maintaining the skin markings. Often times the tattoo markings are not the location of the treatment area but are used to as a guide for treatment shifts. Shifts are made from the tattooed areas and are then marked on the skin with sharpie; "…these markings typically are covered by adhesive tape during the course of the treatment to maintain their integrity, which might cause skin irritation on delicate soft tissue from the chemical properties found in adhesive stickers" (Nutt, 2023, p. 98). Patients also might experience body habitus changes and weight loss during radiation treatments. This can cause changes with the elasticity of the skin cause issues with the positioning using the traditional three-point technique (Nutt, 2023, p. 99).

Comparison to SGRT

Many studies have been done comparing SGRT to the traditional triangular positioning. It has been distinguished that the traditional triangular positioning results in more deviations than the SGRT positioning, "…3-point localization was noted to have a significant deviation from the norm compared with the surface imaging, with the most significant deviation noted in breast treatments" (Nutt, 2023, p. 98). Studies have also shown a higher level of patient discomfort

when compared to triangular localization. Immobilization devices are required for the standard traditional triangular positioning because it does not provide live anatomical monitoring. These immobilization devices, such as the aquaplast head and neck masks, provide more discomfort, "the standard of care for patients undergoing head and neck IMRT typically involves the use of closed-face thermoplastic masks, which provide rigid constriction to ensure reproducible positioning of the area of interest. However, the surface scan for SGRT requires optical visualization with the patient's skin to form a 3-D rendering of the patient's surface outline, thus requiring the patient's face to be unobscured for SGRT to the head and neck region" (Nutt, 2023, p. 99). Real-time monitoring and accuracy can also be compared; SGRT "…can detect patient movement during treatment, in contrast to…" traditional triangular IGRT where patient positioning is only verified during the image acquisition before the treatment (Swinnen et al., 2020).

Conclusion

Surface guided radiation therapy is a non-radiographic non-invasive system that provides intrafraction monitoring during treatments and assists in patient positioning and reproducibility. The system comprises of three non-invasive scanners that generate a three-dimensional configuration of the patient's surface representing directional thresholds useful for positioning and treatment accuracy. SGRT provides many benefits such as improved patient set-up, improved accuracy, and reproducibility, decreased dose, and patient comfort. Previous studies verify improved accuracy and patient comfort with the use of SGRT when compared to traditional triangular positioning.

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