Review Article

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Surface Guided Radiation Therapy (SGRT): A Comprehensive Review

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Abstract

Surface-Guided Radiation Therapy (SGRT) is an emerging technology that enhances precision in radiation oncology by using real-time optical surface imaging to monitor patient positioning and motion. This review outlines the principles of SGRT, its clinical applications, advantages over traditional positioning methods, and current limitations, while also exploring future directions in its development and integration into radiotherapy workflow.

Keywords: Surface-Guided Radiation Therapy; patient positioning; motion management; Deep Inspiration Breath Hold; Stereotactic treatment.

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Introduction

Surface-Guided Radiation Therapy (SGRT) is an advanced technology used in modern radiation oncology to enhance the treatment precision and patient safety. Unlike traditional positioning methods that rely on skin markings, tattoos or immobilization devices, SGRT uses real-time optical imaging to track a patient's body surface during radiation delivery without adding extra radiation dose (Al-Hallaq H1). At the core of SGRT is the use of 3D camera systems that project a light pattern onto the patient's skin and capture thousands of data points to create a highly accurate surface map. This surface is continuously compared to a reference model generated during treatment planning, allowing clinicians and radiotherapists to detect even minimal patient movement in real time. Radiation therapy relies heavily on accurate patient positioning and motion management to ensure precise and accurate dose delivery to target volumes while minimizing exposure to surrounding healthy organs at risk. Conventional techniques, such as laser alignment and skin tattoos, have limitations in reproducibility and patient comfort. SGRT addresses these issues by providing a non-invasive, marker-free approach to patient setup and monitoring [1-5].

SGRT systems utilize stereoscopic camera arrays to project structured light onto the patient's surface and capture 3D images. These images are compared in real time to a reference surface acquired during simulation. Any deviations in patient positioning are detected instantly, allowing for corrections before and during treatment delivery. It involves continuously capturing the patient's 3D surface in real time using optical imaging, without the need for external markers (Al-Hallaq H2) [6].

Key components of SGRT include:

*Optical camera systems

*Surface reconstruction algorithms

*Real-time motion tracking software

SGRT is particularly beneficial in treatments requiring high precision, such as breast cancer, head and neck cancers, and stereotactic procedures. For example, in deep inspiration breath hold (DIBH) technique used for left-sided breast cancer, SGRT helps monitor the patient's breathing and ensures the radiation is delivered only when the patient's chest is in the correct position, thereby reducing radiation exposure to the heart and lungs. There are many SGRT firms available. The short comparison among vendors have been shown in Table1.

Table 1. Comparison of commercially available SGRT vendors.

Vendor	Camera size	Camera Resolution	Number of Cameras	Frame Rate	Registration algorithm	Interface with linac
AlignRT Horizon (VisionRT)	127x480x140 mm; 3.5kg	4096x2160 px (8MP)	1-3	8-25 fps	Rigid	Auto Patient selection, beam-hold, couch shift
Catalyst + (C-RAD)	620x390x280 mm; 16kg	640x480 px (0.3 MP	1-3	8-24 fps	Deformabel	Auto Patient selection, beam-hold, couch shift
IDENTIFY (Varian)	500x500x400mm; 3.3kg	1280x1024 px (1.3 MP)	3	10 fps	Rigid	Auto Patient selection, treatment record push
ExacTrac Dynamic (Brainlab)	200x370x310mm; 9.7kg	640x512 px (0.3MP)	1	15-20 fps	Rigid	Auto Patient selection, beam-hold

In many Surface Guided Radiation Therapy systems, the vendor provides a dedicated calibration plate or phantom that is placed at the treatment machine isocenter to establish the spatial relationship between the camera coordinate system and the linear accelerator coordinate system (Paxton AB3). The purpose of this calibration is to ensure that: The SGRT system's reported patient position corresponds accurately to the machine isocentre. Couch shifts derived from the surface system are geometrically correct. Rotational and translational offsets are referenced consistently with the treatment machine. The optical system remains aligned after installation, service, or camera movement [5-7].

Clinical Applications

Breast Treatment

Traditionally, breast patients were positioned using skin tattoos/marks aligned to room lasers (RB Jimenez4) and verification imaging such as MV portal imaging or kV imaging.

SGRT offers a non-ionizing alternative by using the patient's external surface as the positioning reference. Potential advantages compared with tattoos and portal imaging include elimination or reduction of permanent tattoos, no additional imaging dose, improved patient comfort, faster setup workflows, better rotational correction capability, real-time motion monitoring, support for techniques such as Deep Inspiration Breath Hold (DIBH).

Patient Setup and Positioning

SGRT improves setup accuracy by aligning the patient's surface with the planned treatment position. It reduces reliance on skin markings and enhances reproducibility across treatment sessions.

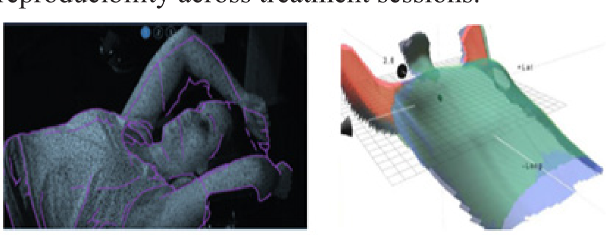

Figure 1. Patient setup and positioning for surface-guided radiation therapy (SGRT) using VisionRT (left) and C-RAD (right)

Motion Management

One of the most significant applications of SGRT is intrafraction motion monitoring. It enables continuous tracking of patient movement, particularly useful in treatments involving respiratory motion such as breast and lung cancers.

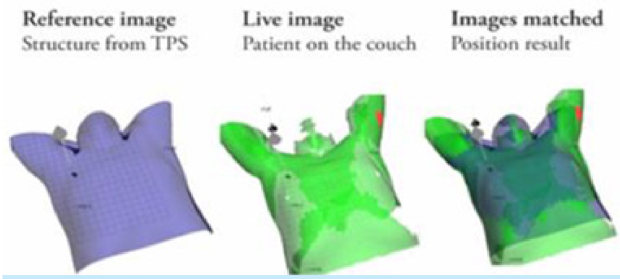

Figure 2. Surface registration process in surface-guided radiation therapy (SGRT): Reference surface generated from the treatment planning system (left); live patient surface acquired on the treatment couch (centre); matched surfaces showing the resulting alignment and positional agreement (right).

Deep Inspiration Breath Hold (DIBH)

Deep Inspiration Breath Hold is a technique commonly used during radiation therapy especially for left-sided breast cancer to reduce radiation exposure to the heart and lungs. SGRT is widely used in DIBH techniques, especially for left-sided breast cancer chest wall irradiation, regional lymph node irradiation. By monitoring the patient's surface during breath hold, SGRT ensures consistent lung inflation and reduces cardiac dose. For the period of treatment: The cameras project patterned light onto the patient, software reconstructs the body surface in real time, and the system compares the live surface to the planned position. During gating: Radiation beam turns on only when the surface is within tolerance and if the patient exhales or shifts, the treatment beam pauses automatically. (Figure 3)

Stereotactic Treatment

In high-precision treatments such as stereotactic radiosurgery (SRS) and stereotactic body radiation therapy (SBRT), SGRT provides an additional layer of safety by detecting even minimal patient movements. Stereotactic radiation uses very tight

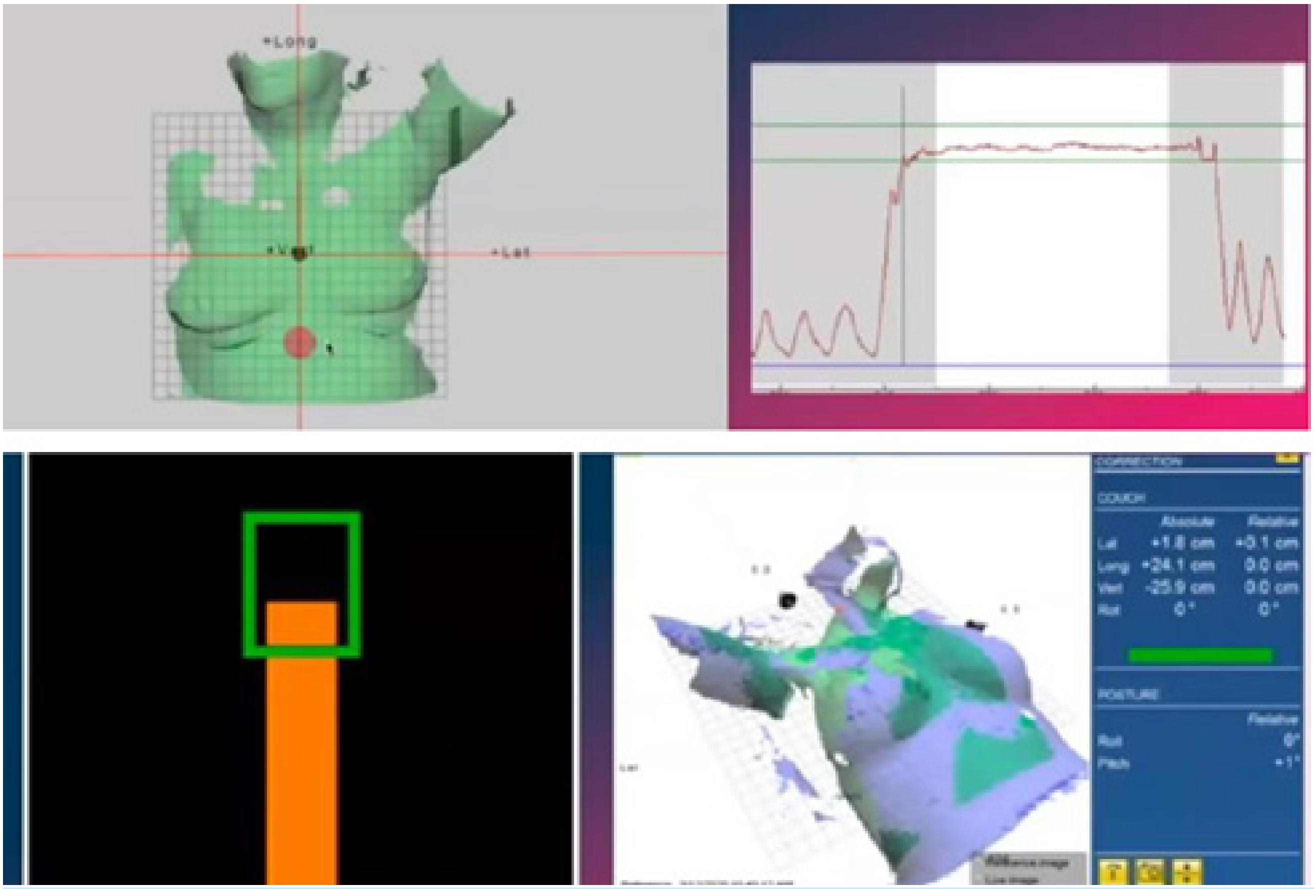

Figure 3. Key components of surface-guided radiation therapy (SGRT) monitoring: 3D patient surface with reference coordinate axes (top left), real-time motion trace showing respiratory signal within gating thresholds (top right); region of interest (ROI) selection for tracking (bottom left); surface matching and positional offsets used for patient alignment and correction (bottom right).

margins and high doses, so precision is critical. SGRT helps reduce setup errors, improve reproducibility between sessions, detect intrafraction motion (movement during treatment), potentially reduce unnecessary radiation to healthy tissues, increase patient comfort by reducing immobilization requirements in some cases.

Key guidance from the American Association of Physicists in Medicine (AAPM) and the European Society for Radiotherapy and Oncology (ESTRO), via its ACROP, outlines how Surface-Guided Radiation Therapy (SGRT) should be used in clinical practice. These documents describe appropriate clinical indications, structured workflows, and essential quality assurance procedures (Batista V 5, Naidoo W 3, Li G 6, Hoisak JDP4 HA Al-Hallaq 2, Freislederer P7). They recommend SGRT particularly for treatments where positioning accuracy and motion monitoring are critical, such as breast radiotherapy (including DIBH), stereotactic treatments, and selected head and neck or paediatric cases. The guidelines emphasize that SGRT should be integrated into the full treatment pathway from simulation and setup to intrafraction monitoring while working alongside, not replacing, image-guided radiotherapy (IGRT). A strong focus is placed on quality assurance, including system commissioning, routine performance checks, and end-to-end validation of workflows. Clear tolerance levels, well-defined clinical protocols, and comprehensive staff training are also highlighted as essential for safe and effective implementation.

Advantage of SGRT

Non-invasive and marker-free: Eliminates the need for tattoos or immobilization devices in some cases.

Real-time monitoring: Allows continuous tracking throughout treatment delivery.

Improved patient comfort: Reduces psychological and physical burden. Enhanced workflow efficiency: Speeds up setup and reduces need for repeated imaging. Reduced imaging dose: Minimizes reliance on ionizing imaging modalities.

Limitations and Challenges

Surface vs internal anatomy: External surface alignment may not always correlate perfectly with internal target position. Initial cost and integration: High setup costs and need for workflow adaptation. Training requirements: Staff must be adequately trained to use and interpret SGRT data.

Conclusion

SGRT represents a significant advancement in radiation therapy, offering improved treatment accuracy, safety, and patient experience. While challenges remain, ongoing technological developments and clinical validation are expected to solidify its role as a standard component in modern radiotherapy.

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