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abstract

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Improving Setup Precision in DIBH Radiotherapy for Left-Sided Breast Cancer: Tattoo-less vs. Tattoo-Based Surface-Guided and Respiratory Gating Techniques

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Introduction: Deep inspiration breath-hold (DIBH) is a widely used technique to minimize radiation exposure to the heart during radiotherapy for left-sided breast cancer. Several clinical methods are employed to track respiratory motion during DIBH. These include surrogate-guided techniques using a marker box placed near the xiphoid process to monitor chest wall motion, respiratory gating systems such as RGSC (Varian Medical Systems, Palo Alto, CA), and surface-guided radiotherapy (SGRT), which utilizes a real-time three-dimensional (3D) model of the patient's skin surface for positioning and motion monitoring.

Traditionally, permanent skin tattoos are used to assist with patient setup in radiotherapy. However, tattoos can pose challenges for accurate alignment and may negatively impact patients' psychological well-being by serving as a lasting reminder of their cancer experience.

This study aims to compare the setup precision of tattoo-less versus conventional tattoo-based patient positioning techniques during DIBH radiotherapy for left-sided breast cancer. Specifically, the study first evaluates the performance of two respiratory tracking systems—IDENTIFY™ SGRT (Version 3.0.3, Varian Medical Systems, Palo Alto, CA) and RGSC (Version 2.1)—within a tattoo-based workflow. It then retrospectively compares these results with the setup accuracy achieved using a tattoo-less workflow supported exclusively by SGRT.

The broader goal is to determine whether the tattoo-less approach, supported by SGRT systems, can provide setup precision comparable to or better than traditional tattoo-based methods, while potentially improving patient comfort and workflow efficiency.

Methodology: A total of 25 patients with left-sided breast cancer undergoing DIBH radiotherapy

were prospectively enrolled in the study. Each patient received pre-treatment DIBH training and visual feedback during treatment to ensure consistent breath-hold performance. Within this cohort, patients were initially treated using a tattoo-based workflow. The first half of their treatment fractions were delivered using the RGSC system (n=200) followed by the remaining fractions using the IDENTIFY™ SGRT system (n=200). Both systems operated within a tattoo-based setup approach. Positioning accuracy was assessed using orthogonal images acquired during DIBH, and translational shifts recorded by each system were retrospectively compared.

Further to evaluate tattoo-less positioning, a separate cohort of 25 patients (n=200) treated exclusively using the tattoo-less (TTL) SGRT workflow was included for comparison. These patients also underwent pre-treatment training and real-time visual feedback during DIBH. Statistical analysis was conducted to compare setup accuracy between the different workflows using a Pitman-Morgan variance test, with significance defined as $p < 0.05$.

Results: In the prospective study, the mean magnitudes of the three-dimensional (3D) shift vectors were 6.9 ± 2.1 mm for surface-guided radiotherapy (SGRT) and 7.6 ± 2.4 mm for respiratory-gated surface control (RGSC), demonstrating a statistically significant difference ($p = 0.02$). Moreover, SGRT exhibited reduced mean translational shifts across all three axes compared with RGSC, with statistically significant improvements observed in the vertical and longitudinal directions. Specifically, the mean translational shifts with RGSC were 9.0 ± 2.5 mm (vertical), 6.1 ± 2.4 mm (longitudinal), and 5.2 ± 3.0 mm (lateral), compared with 7.0 ± 1.2 mm, 4.1 ± 1.1 mm, and 4.5 ± 2.5 mm, respectively, using SGRT (Fig. 1). These findings indicate a strong correlation between SGRT and RGSC, with SGRT providing comparable or improved positioning accuracy.

In the retrospective analysis, the tattoo-less setup using IDENTIFY™ SGRT demonstrated a further reduction in average absolute translational shifts, with values of 0.07 ± 0.02 mm (vertical), 0.07 ± 0.01 mm (longitudinal), and 0.05 ± 0.01 mm (lateral). Statistical evaluation also confirmed significantly enhanced positioning precision with the tattoo-less (TTL) method, as reflected by an average 3D shift vector of 3.5 ± 0.2 mm ($p = 0.01$).

Conclusion: This study demonstrates that digital oncology solutions must be rooted in socio-cultural realities to achieve meaningful adoption. While computational modules such as real-time video communication and staging algorithms are essential, the greatest impact arises from aligning system design with patient experiences, caregiver practices, and cultural accessibility. By bridging technological innovation with user-centered insights, the proposed cancer care platform offers a feasible path to strengthen oncology care in resource-limited settings like Bangladesh.

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