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Detection of setup uncertainties with 3D surface registration system for conformal radiotherapy of breast cancer

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ABSTRACT

Aim: To investigate the clinical application of a technique for patient set-up verification in breast cancer radiotherapy based on a 3D surface image registration system.
Background: Accurate and reproducible patient set-up is a prerequisite to correctly deliver fractionated radiotherapy. Various approaches are available to verify and correct patient setup for 3D image acquisition in a radiation treatment room.
Materials and methods: The study analyzed the setup reproducibility of 15 patients affected by breast cancer and candidates for conformal radiotherapy by using the AlignRT system (VisionRT, London, UK). At the initial setup, electronic portal imaging device (EPID) images were compared with Digitally Reconstructed Radiographs (DRRs) and a reference three-dimensional (3D) surface image was obtained by AlignRT. Surface images were acquired prior to every subsequent setup procedure. The systematic and random errors along longitudinal and vertical directions were measured and compared for the two systems.
Results: The procedure for surface registration, image acquisition and comparison with the reference image took less than 1 min on average. The *T* test for systematic error showed no significant difference between the 2 verification systems along the longitudinal ($p = 0.69$) and vertical ($p = 0.67$) axes. The *T*-test for random error showed a significant difference between the 2 systems along the vertical axis ($p = 0.05$).
Conclusion: AlignRT is fast, simple, non-invasive and seems to be reliable in detecting patient setup errors. Our results suggest that it could be used to assess the setup reproducibility for breast cancer patients.

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1. Background

Accurate and reproducible patient setup is a prerequisite to correctly deliver fractionated radiotherapy. Minimizing the position uncertainties in order to reduce the safety margins around the clinical target volume (CTV), i.e. the planning target volume (PTV), can be of great relevance especially when using highly conformal techniques such as intensity modulated radiation therapy (IMRT).[1–3]

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Various approaches are available to verify and correct patient setup for three-dimensional (3D) image acquisition in a radiation treatment room. These include standard megavoltage electronic portal imaging device (EPID),[4] megavoltage and kilovoltage computed tomography (CT) by helical and cone beam techniques[5] as well as ultrasound systems.[6] Alternatively, optical systems can be used to reconstruct the 3D coordinates of markers fixed to the patient.[7,8] The latter technique, which requires no additional radiation exposure, has been employed in various tumour locations[9,10] and can be of particular relevance when applied to targets located near the skin and the subcutaneous tissues like mammary gland.[11]

2. Aim

In the present study, we investigated a method for verifying and correcting treatment setup errors using a 3D surface imaging system installed in the treatment room to facilitate image-guided radiotherapy in breast cancer patients.

3. Materials and methods

3.1. *Image acquisition system*

The commercially available 3D surface image registration system AlignRT (Vision RT, London, UK) was installed in a treatment room equipped with a linear accelerator with multileaf collimator and amorphous silicon EPID (see Fig. 1). The AlignRT system consists of two imaging pods mounted on the ceiling under an oblique angle of 30° with respect to the treatment table. Each pod containing two stereo-vision cameras, a texture camera, a clear flash, a flash used for speckle projection and a slide projector for speckle projection, acquires 3D surface data over approximately 120° in the axial plane, from midline to posterior flank. The data are merged to form a single 3D surface image of the patient. The system includes software designed to facilitate patient setup by surface-model acquisition and alignment by surface matching with a reference image that can be obtained at the time of first treatment session by extraction of the surface image from CT data. In order to optimize the alignment process, the software is able to calculate the optimal rigid-body transformation (couch translation and rotation) that brings the surface model of the daily treatment fraction into congruence with the reference surface.

Fig. 1 – Photograph of the two camera pods (black arrows) of the surface registration system, mounted on the ceiling of the treatment room. The linear accelerator is also shown.

Before starting the clinical activity, a test was performed in order to verify the performance of the system in terms of precision and reproducibility of the measures as described in a previous article.[10] An anthropomorphic phantom was positioned on the treatment table and aligned with the three laser system of the treatment room. Known shifts of the treatment table along the three axes were checked by the AlignRT with measurements for each axis X, Y and Z. The system demonstrated high accuracy and reproducibility with measured errors of less than 1 mm. A quality assurance procedure was adopted for the AlignRT system by daily checks to calibrate the cameras to the coordinates of the linear accelerator using a dedicated calibration plate with a printed grid.

3.2. *Clinical series*

Fifteen patients aged from 36 to 76 years (mean 55 years), operated by conservative surgery for breast cancer, were enrolled in the present study after having given their informed consent following the rules of our institution. All patients underwent simulation by helical CT-scan (Lightspeed, General Electric, Milwaukee, WI, USA) in a supine position with contiguous slices of 5 mm in thickness. The breast Posiboard system (CIVCO, Kalona, USA) was used for patient setup. Three skin tattoos, two anteriors and one lateral, were marked for position verification by alignment to the 3 laser system.

CT data were transferred to the treatment planning system Pinnacle 8.0 (ADAC, Philips, Eindhoven, the Netherlands). Target volumes and organs at risk (OARs) (ipsilateral lung and heart) were outlined. The CTV was defined as the entire breast tissue starting 5 mm below the skin. The PTV was obtained by adding 10 mm margin to the CTV, except in the direction of the skin. Treatment consisted of 3D-conformal radiotherapy using tangential fields to a total dose of 50 Gy in 25 fractions in 10 cases and of 45 Gy in 20 fractions in 5 cases. Subsequently, all patients received 9 Gy electron boost dose to the surgical bed delivered in 3 fractions of 3 Gy each.

3.3. *Image acquisition*

During the first treatment session, portal images of the two tangential treatment fields were acquired with a double exposure and compared with the treatment plan Digitally Reconstructed Radiographs (DRRs). At the same time, a reference surface image of the thorax (from the supraclavicular region to submammary sulcus) was obtained and recorded by the AlignRT system. Surface images were acquired daily during every setup procedure and co-registered with the reference image obtained at the first treatment session. Portal images were acquired in the first 3 days and then once a week. The setup errors detected by EPID were retrospectively compared with those produced by the surface imaging system. Setup deviations measured by EPID were decomposed along the main axis of the treatment tangential fields, and the setup errors measured by means of the AlignRT system were acquired in the treatment room reference system, which

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