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Estimation of optimal matching position for orthogonal kV setup images and minimal setup margins in radiotherapy of whole breast and lymph node areas

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ABSTRACT

Aim: The aim was to find an optimal setup image matching position and minimal setup margins to maximally spare the organs at risk in breast radiotherapy.

Background: Radiotherapy of breast cancer is a routine task but has many challenges. We investigated residual position errors in whole breast radiotherapy when orthogonal setup images were matched to different bony landmarks.

Materials and methods: A total of 1111 orthogonal setup image pairs and tangential field images were analyzed retrospectively for 50 consecutive patients. Residual errors in the treatment field images were determined by matching the orthogonal setup images to the vertebrae, sternum, ribs and their compromises. The most important region was the chest wall as it is crucial for the dose delivered to the heart and the ipsilateral lung. Inter-observer variation in online image matching was investigated.

Results: The best general image matching position was the compromise of the vertebrae, ribs and sternum, while the worst position was the vertebrae alone ($p \leq 0.03$). The setup margins required for the chest wall varied from 4.3 mm to 5.5 mm in the lung direction while in the superior–inferior (SI) direction the margins varied from 5.1 mm to 7.6 mm. The inter-observer variation increased the minimal margins by approximately 1 mm. The margin of the lymph node areas should be at least 4.8 mm.

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Conclusions: Setup margins can be reduced by proper selection of a matching position for the orthogonal setup images. To retain the minimal margins sufficient, systematic error of the chest wall should not exceed 4 mm in the tangential field image.

1. Background

Radiotherapy (RT) of the breast is a challenging task. The shape of the breast may vary both intra- and inter-fractionally. Moreover, respiratory breathing cycle causes uncertainties in the treatment localization. The breast may move up to 1 cm[1] with respiration while the average motion has been found to vary from 2 to 4 mm, similar to that of the chest wall.[2] Recently, breathing control techniques such as gating[3] or voluntary deep inspiration breath hold (vDIBH)[4] have been introduced. Unfortunately, these techniques are resource-intensive and cannot be applied for non-cooperative patients or patients with reduced breath-holding capability. While the target shape may best be evaluated with 3D techniques, such as cone beam computed tomography (CBCT),[5] the frequency of 3D acquisitions varies considerably between the centers and routine treatment setup is usually based on 2D images. Moreover, there is no clear consensus on the benefits of the CBCT for standard breast cancer patients.[6] Therefore, investigation of target localization with 2D position verification still remains highly relevant.

The existing 2D image guided radiotherapy (IGRT) protocols vary considerably between centers. Some clinics use merely orthogonal setup images or tangential images from treatment beam directions while others use both of these.[7] The breast itself is not visible in the orthogonal setup images and choice of the representative anatomic landmarks for image alignment is not a straightforward task because the correlation of the landmarks with the breast is not obvious. On the other hand, the breast is visible in the tangential images but these are susceptible to respiratory motion. Moreover, it is impossible to decide appropriate couch corrections in anterior–posterior and lateral directions based merely on the tangential images. Therefore, acquisition of orthogonal images or patient re-simulation is needed, when the setup errors exceed the tolerances in the tangential Images.[8]

The guidelines of the matching position vary for the orthogonal images. Some centers use the sternum and the ribs[9] while others include also the vertebrae[6] or use the vertebrae alone. To the best of our knowledge, residual position errors in the tangential images have not previously been evaluated and compared for different matching positions of the orthogonal setup images.

2. Aim

In this study, we investigated residual position errors in the tangential treatment field images when the orthogonal setup images were aligned in different ways. These alignments were based on relevant bony landmarks, such as the vertebrae, the sternum, the ribs and their combinations. The aim was to find the best landmarks with the smallest position errors and thus minimal setup margins to maximally spare the organs at risk. The magnitude of margins is most pronounced with modern intensity modulated techniques providing highly conformal dose distributions.[10] We evaluated inter-observer variation in the image matching advised to the optimal matching position by determining residual errors in the online IGRT performed by 25 experienced radiation therapists. Moreover, we determined residual errors of the landmarks relevant for the lymph node areas after the online match.

3. Materials and methods

3.1. *Patient group and the IGRT protocol*

A total of 50 consecutive left-sided breast cancer patients receiving adjuvant radiotherapy after breast conserving surgery were included in this study. The mean patient age was 63 years. The patients were immobilized with Candor's Con-Bine fixation device (Candor, Gislev, Denmark) with both arms elevated above the head. The device has adjustable arm supports and head cushion. The palm of contralateral hand was attached to the wrist of the ipsilateral hand. CT imaging for treatment planning was done with free breathing at 120 kVp with either Philips Brilliance Big Bore (Philips Medical Systems, Eindhoven, The Netherlands) or Toshiba Aquilion LB (Toshiba Medical System, Tokyo, Japan) scanners using a slice thickness of 3 mm. In our setup protocol, skin tattoo marks for laser setup were placed on the patients' sternum and below the breast. Patients were treated to 50 Gy at 25 fractions with the two tangential field technique ($n = 25$) or four-field technique for lymph node irradiation (axillary and supraclavicular areas, $n = 25$) using 6 MV photon beams of Clinac 2300 iX accelerator (Varian Medical Systems, Palo Alto, CA).

The orthogonal kV-images were acquired daily with an onboard imaging system (OBI) at 75 kV/200 mA/25 ms for anterior images and at 95 kV/200 mA/200 ms for lateral images. The orthogonal kV images were used for couch translational corrections. The daily image guidance (IGRT) protocol included also a tangential MV field image acquired after the couch corrections for final verification of treatment localization. The dose related to the MV imaging (2 monitor units per image) was taken into account in the treatment planning. The acquired onboard images were analyzed retrospectively offline. All together, 1111 orthogonal X-ray image pairs and tangential field images were analyzed. 139 image sessions were not imaged for unknown reasons.