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PHYSICS CONTRIBUTION

BREAST-CONSERVING THERAPY: RADIOTHERAPY MARGINS FOR BREAST TUMOR BED BOOST

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Purpose: To quantify the interfraction position variability of the excision cavity (EC) and to compare the rib and breast surface as surrogates for the cavity. Additionally, we sought to determine the required margin for on-line, off-line and no correction protocols in external beam radiotherapy.
Methods and Materials: A total of 20 patients were studied who had been treated in the supine position for 28 daily fractions. Cone-beam computed tomography scans were regularly acquired according to a shrinking action level setup correction protocol based on bony anatomy registration of the ribs and sternum. The position of the excision area was retrospectively analyzed by gray value cone-beam computed tomography-to-computed tomography registration. Subsequently, three setup correction strategies (on-line, off-line, and no corrections) were applied, according to the rib and breast surface registrations, to estimate the residual setup errors (systematic [Σ] and random [σ]) of the excision area. The required margins were calculated using a margin recipe.
Results: The image quality of the cone-beam computed tomography scans was sufficient for localization of the EC. The margins required for the investigated setup correction protocols and the setup errors for the left–right, craniocaudal and anteroposterior directions were 8.3 mm (Σ = 3.0, σ = 2.6), 10.6 mm (Σ = 3.8, σ = 3.2), and 7.7 mm (Σ = 2.7, σ = 2.9) for the no correction strategy; 5.6 mm (Σ = 2.0, Σ = 1.8), 6.5 mm (Σ = 2.3, σ = 2.3), and 4.5 mm (Σ = 1.5, σ = 1.9) for the on-line rib strategy; and 5.1 mm (Σ = 1.8, σ = 1.7), 4.8 mm (Σ = 1.7, σ = 1.6), and 3.3 mm (Σ = 1.1, σ = 1.6) for the on-line surface strategy, respectively.
Conclusion: Considerable geometric uncertainties in the position of the EC relative to the bony anatomy and breast surface have been observed. By using registration of the breast surface, instead of the rib, the uncertainties in the position of the EC area were reduced. © 2008 Elsevier Inc.

Breast cancer, Setup errors, Treatment margins, Cone-beam computed tomography-guided radiotherapy, Correction strategies.

INTRODUCTION

Breast-conserving surgery followed by radiotherapy (RT) is a standard treatment option for early-stage breast cancer patients. The visible tumor is removed during surgery, and afterward RT is delivered to the breast area that might contain microscopic disease (1). Most breast cancer recurrences appear in the region of the excision cavity (EC). Separate randomized trials have shown that tumor recurrences can be reduced by dose escalation to the EC region (2, 3). The radiation boost can be delivered using a sequential boost (4, 5) or a simultaneously integrated boost (SIB) technique (6–8). At our institute, the SIB technique is used clinically.

Another approach to breast cancer treatment using external beam RT is to irradiate only the EC region. Because most breast cancer recurrences appear in the region of the EC (9), Baglan *et al.* (10) developed an accelerated partial breast irradiation (APBI) technique. However, the APBI technique is not yet standard. It is currently in the experimental phase, and additional follow-up of patients is needed to quantify the outcome and success rate.

Several challenges are associated with breast/boost irradiation. The first is related to delineation uncertainties: limited surgery precision, uncertainty in the correlation with the pathologic findings, and interobserver variability in target delineation on computed tomography (CT) (11, 12). The second is position verification of the EC. The lumpectomy scar is not a good surrogate for the position of the EC, as delineated by using surgical clips (13, 14). Some breast

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radiation oncologists consider the surgical clips as a reference standard for localization of the EC (15). However, by inspecting two subsequent CT scans with an average difference of 27 days, Weed *et al.* (16) observed that surgical clips moved with respect to the EC by 3 mm.

At our institute, cone-beam CT (CBCT) systems (Elekta Synergy, Elekta Oncology Systems, Crawley, West Sussex, UK) (17) are used for bony anatomy setup verification of breast cancer patients. The CBCT systems also allow for the visualization of soft-tissue structures in the breast that can be used to quantify the interfraction position variability of the EC. Furthermore, the systematic error (Σ), random error (σ), and margin size of the EC can be calculated (18). In recent studies, White *et al.* (19) and Kim *et al.* (20) used CBCT scans to estimate the Σ, σ, and margins for the EC using on-line correction protocols.

The purpose of the present study was to quantify the interfraction position variability of the EC and to determine the required margin for the boost volume for on-line, off-line, and no correction protocols, using either the position of the ribs or of the breast surface as a surrogate for the EC position.

METHODS AND MATERIALS

Patients

A total of 20 breast cancer patients were included in our study. All had undergone breast-conserving surgery before RT. The patients had no seroma owing to approximation (stitching up) of the tumor bed after lumpectomy. The EC was identified and delineated by radiation oncologists. They used *(1)* preoperative magnetic resonance imaging, ultrasonography, and mammography, *(2)* reports written by the surgeons and pathologists, and *(3)* postoperative planning CT scans. Of the 20 patients, 9 had a right-sided tumor and 11 a left-sided tumor. For each patient, the position of the EC was defined in three directions: lateral-central-medial, upper-central-lower, and superficial-central-rib (Fig. 1). Furthermore, the distances between the EC center of mass and the ribs and between the surface and the ribs in the transversal plane were calculated. Finally, the EC volume and target/breast volume were calculated (Table 1). The target/breast volume was defined by computing the tissue (excluding lung) within the open beams, reduced by a margin of 7mm from the peripheral side and 5 mm from the chest wall side. Planning CT scans were acquired with a 4.8-mm slice thickness. The CT images were used for treatment planning (Pinnacle, version 7.4f, Philips Radiation Oncology Systems, Milpitas, CA) and as a reference for image guidance and quantification of the EC interfraction position variability during RT. The patients were treated with a SIB technique in the supine position for 28 daily fractions to 64.4 Gy. A dose of 50.7 Gy was prescribed to the whole breast and an additional 13.7 Gy to the boost region. The patients were immobilized using arm supports (developed in-house) and knee supports (CIVCO Medical Solutions, Orange City, IA).

CBCT acquisition

In this investigation, the CBCT scans were acquired with a slow (9 patients) or fast (11 patients) scan method over an angle of 200°. The acquisition time of the slow method was approximately 4 min. The slow CBCT scans were composed of approximately 1,350 projections, and each projection was acquired using 120 kVp, 16 mA, and 10 ms. The acquisition time of the fast scans was approximately 1 min, which yielded four times fewer projections. Each projection was acquired using 120 kVp, 16 mA, and 40 ms. The skin dose to the patient was 1.2–1.5 cGy/scan for both methods (21).

Registration

Bony anatomy. Rigid registration of the bony anatomy was performed within a user-defined box-shaped region of interest (ROI) according to a chamfer matching algorithm (22). In clinical practice at our institute, the ribs on the irradiated side and sternum are used for registration of the CBCT scans with the planning CT scans. This choice is a compromise between minimizing the uncertainties in the position of the breast and the organs at risk (*i.e.,* heart and lungs). The rib match was performed routinely by 2 radiation technologists.

Soft tissue. Local rigid registration of the soft tissue was performed using a three-dimensional ROI defined in the planning CT scan. Subsequently, the CBCT scan was automatically registered to the ROI using a correlation ratio (23) of all voxels in the ROI

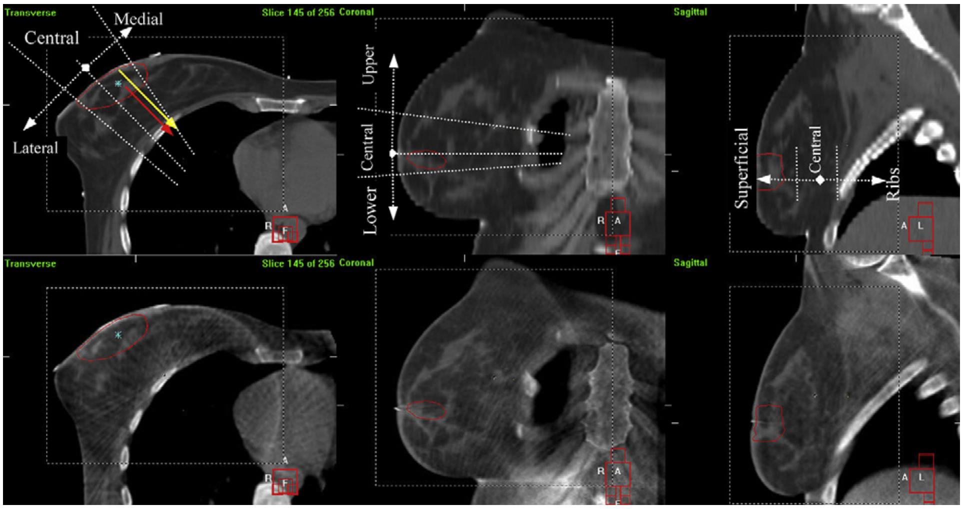

Fig. 1. (Top) Planning computed tomography scan of Patient 3 and (Bottom) slow cone-beam computed tomography scan of same patient. Note, breast split in medial-central-lateral, upper-central-lower, and superficial-central-ribs direction (Top); distances between excision cavity center of mass and ribs (red arrow) and surface and ribs (yellow arrow) also shown.