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Dosimetric feasibility of an “off-breast isocenter” technique for whole-breast cancer radiotherapy

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ABSTRACT

Aim: To investigate the viability of placing the treatment isocenter at the patient midline for breast cancer radiotherapy in order to avoid the risk of collisions during image-guided setup and treatment delivery.

Background: The use of kilovoltage orthogonal setup images has spread in last years in breast radiotherapy. There is a potential risk of an imaging system–patient collision when the isocenter is laterally placed.

Materials and methods: Twenty IMRT plans designed by placing the isocenter within the breast volume (“plan_ref”), were retrospectively replanned by shifting the isocenter at the patient’s midline (“plan_off-breast”). An integrated simultaneous boost (SIB) technique was used. Multiple metrics for the planning target volumes (PTVs) and organs at risk (OARs) were compared for both approaches using a paired *t* test.

Results: Comparing plan_ref vs. plan_off-breast, no significant differences in PTV coverage (V95%) were found (96.5% vs. 96.2%; $p = 0.361$ to PTVbreast; 97.0% vs. 97.0%; $p = 0.977$ to PTV-tumor_bed). With regard to OARs, no substantial differences were observed in any analyzed metric: V5Gy (30.3% vs. 31.4%; $p = 0.486$), V20Gy (10.3% vs. 10.3%; $p = 0.903$) and mean dose (7.1 Gy vs. 7.1 Gy; $p = 0.924$) to the ipsilateral lung; V5Gy (11.2% vs. 10.0%; $p = 0.459$), V30Gy (0.7% vs. 0.6%; $p = 0.251$) and mean dose (2.3 Gy vs. 2.2 Gy; $p = 0.400$) to the heart; and average dose to the contralateral breast (0.4 Gy vs. 0.5 Gy; $p = 0.107$).

Conclusions: The off-breast isocenter solution resulted in dosimetrically comparable plans as the reference technique, avoiding the collision risk during the treatment session.

1. Aim

This work describes a practical planning solution to avoid collisions between the on-board imaging (OBI) system of the linear accelerator (linac) and the patient that may occur during an image-guided protocol used in our department for breast radiotherapy. The solution consists in shifting the lateral position of the treatment isocenter at the center of the couch, instead of the traditional way of placing it inside the breast

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volume. We conclude that there are no significant dosimetric differences between the proposed "off-breast isocenter" planning technique and the traditional approach.

2. Background

Breast cancer is the most common cancer in women worldwide.[1] Adjuvant radiotherapy following breast-conserving surgery significantly improves the overall survival of breast cancer patients.[2] Radiotherapy has been traditionally performed sequentially, i.e., after completion of whole breast irradiation, with doses of 1.8–2.0 Gy per fraction to a total dose of approximately 50 Gy, a boost dose is delivered to the tumor bed. This boost may be applied using external photon and/or electron beams up to a total dose of 60–66 Gy in same fractional dose sizes as a preceding whole breast irradiation.

A simultaneous integrated boost (SIB) approach was proposed as an alternative to the traditional sequential boost practice. SIB consists in delivering the boost to the tumor bed simultaneously with the whole breast irradiation.[3] The use of a SIB schedule for the breast cancer irradiation was initially reported by Smitt et al.[4] and Guerrero et al.,[5] resulting in an improved dose distribution and reduced number of treatment fractions. SIB using intensity-modulated radiotherapy (IMRT) has been reported by several groups, emphasizing the improvement of the dose distribution in the breast and the increased sparing of normal tissues over the conventional treatment.[4–9] The isocenter is often placed at the center of the whole breast and so located several centimeters lateral to patient midline. Due to this issue, the treatment couch often needs to be shifted medially to enable full gantry rotation without couch or patient collisions.

The risk of collision also exists during the patient setup imaging stage in a linac equipped with a kilovoltage (kV) OBI system. The addition of the kV source and detector arms to the linac, in conjunction with the treatment position of the patients with their arms raised and the noncentral isocenter (in respect to the linac couch center in the lateral direction) can make clearance between the patients and the linac problematic.

The mentioned collision risk could be avoided by shifting the isocenter at the lateral midline of the couch (∼patient midline) during the treatment planning, i.e., placed in an off-breast position. In this work, the dosimetric effect of using an off-breast isocenter was evaluated by comparing the target dosage and critical structures dose sparing against our traditional procedure of locating the isocenter inside the breast.

3. Materials and methods

3.1. *Simulation and organ definition*

At our institution, patients with breast cancer are immobilized in supine position using an arm support (with the ipsilateral or both arms above the head) and a knee support (CIVCO Medical Solutions, Orange City, IA). A free-breathing computed tomography (CT) scan is obtained with a 3-mm slice distance. After planning CT is done, the CT images are transferred to a commercially available (Varian, Eclipse 10.0, Varian Medical Systems, Palo Alto, CA) treatment planning system (TPS).

The Radiation Therapy Oncology Group (RTOG) breast cancer atlas[10] was followed as guideline for delineation of the clinical target volumes (CTVs). CTV of the whole breast (CTVbreast) was the entire mammary gland. CTV for boost (CTVboost) was the surgical bed, as defined by surgical clips placed in the lumpectomy cavity during surgery. Planning target volumes (PTVbreast and PTVtumor_bed) were generated from CTVs by adding a 5 mm margin, but limited to 5 mm within the skin surface, and excluding ribs and lung parenchyma. Finally, and for dose calculation purpose, the definitive PTVbreast did not include PTVtumor_bed.

Twenty patients (10 right side/10 left side) treated in our department using an SIB fractionation scheme were retrospectively enrolled in this study. The prescribed dose (PD) was performed in 28 fractions, with 2.3 Gy per fraction to a total dose of 64.4 Gy for the PTVtumor_bed, and 1.8 Gy per fraction to a total dose of 50.4 Gy for the PTVbreast. A Boolean "whole breast" PTV (PTVwb) was generated as PTVtumor_bed or PTVbreast. Volume of PTVwb ranged from 163 cm^3 to 1207 cm^3 with a mean of 463 cm^3. Regarding the organs at risk, the lungs were auto-contoured, while the cardiac silhouette and the contralateral breast were manually outlined. An additional structure called the "healthy tissue" was defined as the total patient body volume minus the PTVwb.

3.2. *Treatment planning*

Every patient enrolled in our study was treated in our department using a SIB-IMRT plan designed by placing the isocenter approximately at the center of the whole breast volume (plan_ref). This approach required a considerable lateral shift of the linac couch (ranged from 8 to 11 cm) to align the patient for treatment delivery.

For each patient case, a coplanar IMRT-SIB reference plan was designed in the Eclipse TPS. The dose was planned using 6 MV photon beams from a Varian 2100 CD linac equipped with the Millennium 120 multileaf collimator (MLC) and the OBI system.

For right-side breast patients, the treatment plan consisted of two tangential fields covering the PTVwb, plus 3–4 oblique fields aiming at the PTVtumor_bed. All beams had the same isocenter. First, the two tangential fields were forwardly optimized (field-in-field IMRT technique) to deliver 50.4 Gy to the PTVwb. Then, boost fields were sequentially planned to give 64.4 Gy to PTVtumor_bed by taking into account the accumulated dose from tangential fields. Two modalities were used for the boost fields: five patients were planned using conformal beams; while boost fields were inversely optimized (sliding-window technique) for the rest of patients.

For left-side breast cases, multiple IMRT fields (sliding-window) were used with all the beam fluences optimized simultaneously. The beam arrangements consisted of two tangential beams irradiating the PTVwb and 2–4 additional ones aiming at the PTVtumor_bed.

The patient dose distribution was calculated with the Anisotropic Analytical Algorithm[11] (AAA), with a 1.0 mm calculation grid size and tissue heterogeneity correction. All SIB