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Simple shielding reduces dose to the contralateral breast during prone breast cancer radiotherapy

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Our goal was to design a prone breast shield for the contralateral breast and study its efficacy in decreasing scatter radiation to the contralateral breast in a prone breast phantom setup receiving radiation therapy designed for breast cancer. We constructed a prone breast phantom setup consisting of (1) A thermoplastic mask with a left-sided depression created by a water balloon for a breast shape; (2) 2 plastic bags to hold water in the thermoplastic mask depression; (3) 2000 mL of water to fill the thermoplastic mask depression to create a water-based false breast; (4) 1-cm thick bolus placed in the contralateral breast holder; (5) 2 lead (Pb) sheets, each 0.1-cm thick for blocking scatter radiation in the contralateral bolus-based false breast; (6) a prone breast board to hold the thermoplastic mask, water, bolus, and lead; (7) 9 cm solid water on top of the breast board to simulate body; (8) a diode was used to verify dose for each treatment field of the treated water-based breast; (9) metal–oxide–semiconductor-field effect transistor (MOSFET) dosimeters to measure dose to the contralateral bolus-based breast. The phantom prone breast setup was CT simulated and treatment was designed with 95% isodose line covering the treated breast. The maximum dose was 107.1%. Megavoltage (MV) port images ensured accurate setup. Measurements were done using diodes on the treated water-based breast and MOSFET dosimeters at the medial and lateral sides of the contralateral bolus-based breast without and with the Pb shield. Five treatments were done for each of the 3 data sets and recorded individually for statistical purposes. All treatments were completed with 6 MV photons at 200 cGy per treatment. The dose contributions from each of the 3 data sets including 15 treatments total without and with the prone lead shield to the medial and lateral portions of contralateral bolus-based breast were averaged individually. Unshielded dose means were 37.11 and 2.94 cGy, and shielded dose means were 12.68 and 1.54 cGy, respectively. When comparing medial and lateral portions of the contralateral bolus-based doses without and with Pb, the shield significantly reduced dose to both sides of the contralateral breast (medial $p = 2.64 \times 10^{-14}$, lateral $p = 4.91 \times 10^{-6}$). The prone 0.2-cm Pb shield significantly reduced scatter dose to the contralateral breast on the order of 2 to 3 times. Reductions may be clinically relevant for women younger than 45 years by decreasing the risk of contralateral radiation-induced breast cancer in patients receiving radiation therapy for breast cancer. This shield is simple as it would be a part of the prone breast board during treatments, but future studies are warranted for safety and efficacy clinically.

Introduction

Women diagnosed with a primary breast cancer are at a 2 to 6-fold increased risk of developing a contralateral breast (CB) cancer compared to the general population risk of developing a primary breast cancer.[1] Radiation therapy (RT) continues to be an important part of breast conserving treatment (BCT) for breast cancer.[2,3] With RT for breast cancer, the CB is within close proximity to receive internal scatter dose in addition to the inevitable external

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scatter and leakage dose. Traditional supine breast RT setups contribute up to 4% to 10% of therapeutic dose to the region 4 to 12 cm from midline into the CB.[4]

The carcinogenic nature of RT for breast tissue has been studied repeatedly,[5-11] leading to efforts in improving RT methods (intensity modulated radiotherapy *vs* 3D conformal radiotherapy, enhanced dynamic wedge, different modes of breathing, daily megavoltage computed tomography with tomotherapy).[12-14] However, these techniques are not without their own caveats such as an increased volume of normal tissue receiving a low dose of RT with intensity modulated radiotherapy or increased treatment time with daily imaging. Despite these efforts, in general, reports do not seem to show a significant decrease in overall CB cancer ranging from 0.5% to 1% per year[15,16] after RT in the supine position. Few studies have elucidated the dose-response risk for CB cancers and provided risk estimations for this toxicity.[7,17-19] Women younger than 45 years exhibit a greater potential relative risk (RR) of CB cancer when treated with adjuvant RT and followed for more than 5 years. The RR is between 1.32 and 1.59 compared to the RR of 1.01 for women older than 45 years.[7,19,20] This is possibly because of a longer life expectancy and premenopausal status.

A large multicenter case-control study found that women under 40 years who received greater than 100 cGy to a specific CB quadrant had a 2.5-times increased risk for CB cancer than an unexposed woman.[19] Patient concerns have arisen because of an overall increased baseline risk of CB cancer from a personal history of breast cancer[21,22] and a perception of an increased risk of recurrence with BCT including lumpectomy and adjuvant radiotherapy.[23] Therefore, more women seem to be opting for contralateral prophylactic mastectomy (CPM) as an alternative treatment option to CB surveillance[24-26] because of cancer anxiety.[27,28] CPM has shown to reduce the risk of CB cancer by 94% but this translates into an insignificant benefit for disease free survival and overall survival.[15,22] Within surgical literature, better patient education regarding BCT *vs* mastectomy local recurrence and CB cancer risks has been suggested.[23,27] Although rates of CPM and risk of radiation-induced CB cancer have not been studied directly, there is a small but increased risk in long-term toxicities such as CB cancer with RT in younger women.[7,19] This may further increase cancer anxiety with BCT during the consent process and lead to patients choosing CPM, so the question arises if radiation oncologists can help to reduce the patient fear of CB cancer risk?

External scatter dose may be a contributor to increased CB cancer risk during breast cancer radiotherapy. To reduce scatter dose to normal tissues, including the CB, shielding has been described by several groups.[29-33] Each of the studies has shown a reduction in CB dose from 50% to 65% in patients treated in the supine position.[30,31] However, a select cohort of patients with breast cancer are treated with RT in the prone position,[34,35] but no studies to our knowledge have evaluated CB dose or shielding using this patient setup. The goal of this investigation was to analyze the RT dose to the CB in the prone position and to examine dose reduction with lead (Pb) shielding.

Methods and Materials

Study setup

A prone breast phantom setup was designed before data collection. This phantom setup was primarily used to prevent any potential complications to a human subject as a prone breast Pb shield for the CB during RT has not been created or tested in another institution to our knowledge. We constructed a prone breast phantom setup (Fig. 1) consisting of (1) an aquaplast thermoplastic mask (Type-S Head, Neck & Shoulder Perforated Mask, CIVCO, Coralville, IA) with a left-sided depression created by a filled water balloon for a breast shape; (2) 2 plastic bags to hold water in the thermoplastic mask depression; (3) 2000 mL water to fill the thermoplastic mask depression to create a water-based breast; (4) 1 cm thick bolus (Bolus, CIVCO Medical Solutions, Coralville, IA) placed in the CB holder; (5) 2 Pb sheets, each 0.1-cm thick (Sheet Lead, Radiation Protection Products, Inc., Wayzata, MN) for blocking external scatter radiation to the contralateral bolus-based breast; (6) a prone breast board (RT-6025/The Prone Breast System, Bionix Radiation Therapy, Toledo, OH) to hold the thermoplastic mask, water, bolus, and Pb; (7) 9 cm solid water (Virtual Water, Standard Imaging, Middleton, WI) on top of the breast board to emulate the body; (8) Central Axis (CAX) diode (InVivo Solutions IVD, Sun Nuclear Corporation, Melbourne, FL) measurements were used to verify the prescribed dose for each treatment field of the treated water-based breast; (9) metal–oxide–semiconductor-field effect transistor (MOSFET) dosimeters (BMC MOSFETs, Best Medical Canada, Ottawa, ON) were used to measure out-of-field dose to the contralateral bolus-based breast.[36-38]

A previous study on supine shielding for breast cancer RT showed that a 0.2-cm Pb was effective in reducing CB dose.[31] Therefore, we chose to study the prone CB dose during breast cancer RT using a CB 0.2-cm Pb shield with our prone breast phantom setup. A 0.2-cm Pb shield was fabricated from 2 Pb sheets, each of 0.1 cm. The Pb sheets were cut by a physicist based on the size and shape of the prone breast board CB holder. The Pb shield was fit together firmly with tape and placed flat within the CB holder under the 1 cm CB bolus daily before treatment.

The breast phantom setup allowed us to conduct separate trials for dose measurements of the contralateral bolus-based breast when the treated water-based breast was undergoing fractionated radiation treatments. A total of 3 radiation trials were done. The phantom was created and setup independently for each trial. Each of the fractionated radiation trials consisted of 5 radiation treatments. A total of 15 paired measurements were performed for each irradiation. These data sets were created for statistical analyses. A radiation treatment included lateral and medial tangential segment weighted fields delivering a prescription dose of 200 cGy per treatment.

Treatment planning

The prone breast phantom setup was simulated with the use of computed tomography (CT) without the 0.2-cm Pb shield. We chose to exclude the Pb shield during the simulation scan because of the scatter artifact that is often seen when high density materials, such as Pb, are present during CT scanning. See Dosimetric considerations section for further details.

Treatment was designed with the 95% isodose line covering the treated water-based breast but excluding the contralateral bolus-based breast (Eclipse Treatment Planning System, Varian Medical Systems, Salt Lake City, UT). Treatment was planned using 2 tangential fields that emulated conventional breast cancer field edges such as the midsternum medially, midaxillary line laterally, and chest wall posteriorly. The prone breast board CB holder was completely avoided when designing the radiation fields. The maximum dose was 107.1% (Fig. 1). Megavoltage (MV) port images were taken to ensure accurate setup. Verification of *in vivo* CAX measurements were done using diodes on the treated water-based breast and MOSFET dosimeters were used for the out-of-field measurements.[36-38] at the medial and lateral sides of the contralateral bolus-based breast without and with the Pb shield. Five treatments were done for each of 3 data sets and recorded individually for statistical purposes. All treatments were completed with 6 MV photons at 200 cGy per treatment (Trilogy System Linear Accelerator, Varian Medical Systems, Salt Lake City, UT).

Dosimetric considerations

The phantom CB was unshielded during CT simulation to avoid scatter artifact from the Pb shield on the CT image that would otherwise need to be added as a structure and density overridden. In addition, if simulating with the Pb shield then the density of the breast tissue would have appeared different than without the Pb shield on the planning CT scan. One density override was required during the treatment planning process to match the surrounding tissue because of a small air gap between the water-based breast and the solid water placed over the prone breast board used to represent the body.

Tangential fields were designed to completely avoid the CB and the area where the Pb shield would be placed. We did not add the Pb shield density within the CB holder during the treatment planning process to avoid directly impacting the treatment planning system calculations and dose-volume histograms of normal structures.

Care in proper placement of the Pb shield and verification of placement was imperative to avoid exit dose and backscatter. The therapists verified that the Pb shield was completely out of the treatment fields before starting RT by using light fields and taking MV port films (Fig. 2).

Data collection

While the treated water-based breast underwent each treatment, a diode was used to verify dose for each treatment field. Diodes were placed at the center of the ipsilateral breast to confirm maintenance of daily prescription dose to the ipsilateral breast, similar to the way our clinic routinely confirms in-field doses for radiotherapy patients undergoing treatment. The measured doses were within 3% from the calculated dose by our monitor units calculation second check software