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CT computer-optimized high-dose-rate brachytherapy with surface applicator technique for scar boost radiation after breast reconstruction surgery

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ABSTRACT

PURPOSE: Immediate breast reconstruction has become increasingly prevalent after mastectomy for breast cancer. Postoperative scar boost radiation for the reconstructed breast presents many planning challenges due to the shape, size, and curvature of the scar. High-dose-rate (HDR) surface applicator brachytherapy is a novel and effective method of delivering scar boost radiation. Two cases, one with a saline implant and one with a transverse rectus abdominis musculocutaneous flap reconstruction, illustrate the method and advantages of HDR optimization of surface applicators.

METHODS AND MATERIALS: For 2 patients a mold of the breast was made with Aquaplast sheets. A reproducible system was used for arm positioning. Skin fiducials, including tattoos from external beam planning, were matched to fiducials on the mold. HDR catheters were sited on the mold at 1 cm intervals, with the central catheter situated along the scar. Topographically, both scars demonstrated extreme curvature in both craniocaudal and mediolateral directions. A CT computer-optimized HDR plan was developed, with the reference dose prescribed at the skin surface. The dosimetry was compared to single-field and matched-field electron plans.

RESULTS: This surface applicator technique provided a uniform skin dose of 100% to the entire clinical target volume (CTV) without hot spots in both patients. The patient position and surface applicator setup were consistently reproducible. The patients tolerated the treatment well with minimal skin erythema. In the single-field electron plan, skin dose was decreased to 50% at the periphery of the scar. Matching fields addressed this depth dose decrement, but resulted in large localized hot spots of more than 200% centrally in each field.

CONCLUSION: CT computer-optimized HDR surface applicator brachytherapy provided a reproducible homogeneous method of treating highly curved scars on the reconstructed breast. Electron beam treatment would result in longer and more complex treatments yet still provide a less homogeneous dose than this surface applicator technique.

Keywords: Brachytherapy; Breast cancer; Breast reconstruction surgery; High-dose-rate; Surface applicator

Introduction

Immediate breast reconstruction after mastectomy for breast cancer has become increasingly prevalent (1). Because mastectomy is frequently chosen for the treatment of locally advanced breast cancer, postoperative radiotherapy is often indicated. Therefore, the number of reconstructed breasts requiring adjuvant postoperative irradiation is also likely to increase. Postmastectomy radiotherapy has been shown to decrease locoregional recurrence and increase disease-free and overall survival when added to systemic therapy for postmastectomy patients (2–4). The rationale for scar boost irradiation is based not on prospective clinical trials but rather on clinical observations of patterns of recurrence. Boost irradiation of the reconstructed breast can present many planning challenges due to the size, shape, and curvature of the resulting scar.

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Surface applicator irradiation is one of the oldest forms of radiotherapy. The construction of wax and paraffin skin molds using radium needles and radon seeds was described at the turn of the 20th century (5). The use of these decreased due to radiation protection issues and the emergence of teletherapy. However, with the introduction of high-dose-rate (HDR) brachytherapy afterloader technology, the use of surface applicators is increasing again. Surface applicators of various designs have been described in the treatment of basal cell and squamous cell carcinoma of the face (5), Kaposi's sarcoma (6), and recurrent chest wall disease even after previous irradiation for breast cancer (7). A novel and effective use of surface applicator technology to deliver adjuvant scar boost irradiation to 2 patients with highly curved scars resulting from breast reconstruction surgery with both saline implant and transverse rectus abdominis musculocutaneous (TRAM) flap reconstruction is presented.

Methods and materials

Two patients underwent mastectomy with immediate reconstruction for breast cancer. Patient 1 received a saline implant and patient 2 had a TRAM flap reconstruction. Both surgical procedures resulted in scars that demonstrated extreme curvature in both craniocaudal and mediolateral directions. The patients were given external beam radiotherapy of 50.4 Gy in 28 fractions to the entire chest wall, including the reconstruction, and presented for additional radiation to the chest wall surgical incision.

To make the surface applicator, the patient was positioned supine with her hand in an easily reproducible position on her hip. The scar was marked with CT compatible wire (Fig. 1a). A mold of the breast and arm was formed using 1-cm-thick Protoplast sheets (WFR/Aquaplast Corp., Wyckoff, NJ). The position of the scar was traced before the sheets opacified (Fig. 1b). HDR catheters (Freiburg flap; Nucletron B.V., Veenendaal, The Netherlands) were placed on the external surface of the Protoplast (WFR/Aquaplast Corp.) mold (Fig. 1c). The central catheter was placed along the projection of the scar, with further catheters placed bilaterally in parallel lines at 1 cm intervals. The number of catheters used was varied according to the margins required for the scar boost. Patients 1 and 2 had seven and five catheters placed to give 2.5 and 2 cm margins around the scar, respectively. This variation was due to individual physician preference for scar boost margins. The catheters were secured with plastic solid strips (WFR/Aquaplast Corp.) (Fig. 1c). Skin fiducials such as moles and tattoos were matched to fiducials on the mold surface to ensure setup reproducibility (Fig. 1d).

A CT planning scan was performed. A computer-optimized HDR plan was developed (see Figs. 3 and 4). Treatment parameters were calculated using 3D treatment planning software (Plato; Nucletron B.V., Veenendaal, The Netherlands). The source dwell times were individually weighted at 0.5 cm intervals to ensure optimal dose distribution. Geometrical optimization was performed to ensure that the 100% isodose matched the skin surface. To maximize homogeneity, the Protoplast sheets (WFR/Aquaplast Corp., Wyckoff, NJ) raised the treatment catheters 1 cm above the skin, giving a skin to isotope distance of approximately 1.5 cm. This extra distance allowed for greater dose uniformity at the skin because the inhomogeneity diminished with distance from the source, as illustrated in Fig. 2. A dose of 2 Gy per fraction was prescribed to be applied at the skin surface. The treatment was given once daily for 5 consecutive days. The dose and fractionation are standard for postmastectomy electron scar boost radiation at this center.

The brachytherapy plan for each case was compared with optimal single-field and matched-field electron plans. The electron plans were constructed from the CT data sets used for the external beam radiotherapy planning. These are shown with bolus of 1 cm for the single field (see Fig. 5) and with normalization to the 80% line for the matched fields (see Fig. 6) as is standard at this center. Electron energy of 6 MeV was prescribed. The beam angles were optimized graphically using Eclipse planning software (Varian Medical Systems, Palo Alto, CA) for the maximum area covered by the normal incidence of the beam. Direct dose comparison was made by visible comparison of isodose lines at the skin surface to ascertain hot and cold spots. The hot and cold spots of the electron beams were quantified at the skin surface within the portals.

Results

Individualized dose optimization allowed the HDR surface applicator to provide a uniform skin dose of 100% to the whole target in both patients. The 80% isodose line lay at a distance beneath the skin surface of 8.4 mm in patient 1 and 6.5 mm in patient 2. This slight variation between patients was due to a difference in the thickness of Protoplast sheet (WFR/Aquaplast Corp.) after it had been stretched slightly during the molding process. Figures 3a and 4a are axial images showing the homogeneous dosimetry of the surface applicator. Figures 3b and 4b are sagittal reconstructions showing the homogeneous dosimetry of the clinical target volume. There were no hot or cold spots in either patient at the skin surface. The applicator setup and patient position were easily and consistently reproducible. This noninvasive procedure was acceptable to the patient. The surface applicator construction and dosimetry could be completed within 3 h, allowing treatment on the same day. The HDR afterloader technique resulted in no radiation exposure to the staff.

In comparison, the single-field electron plan gave an acceptable skin surface dose at the midplane of the scar (Fig. 5a). However, as the target tissue curved away from the midplane, the nonperpendicular incident rays caused