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Skin dose in breast brachytherapy: Defining a robust metric

Michelle Hilts[1,2,*], Heather Halperin[1], Dan Morton[1,2], Deidre Batchelar[1], Francois Bachand[3], Rezwan Chowdhury[3], Juanita Crook[3]

[1]*Medical Physics, BC Cancer Agency, Centre for the Southern Interior, British Columbia, Canada*
[2]*Department of Physics and Astronomy, University of Victoria, British Columbia, Canada*
[3]*Radiation Oncology, BC Cancer Agency, Centre for the Southern Interior, British Columbia, Canada*

ABSTRACT

PURPOSE: To define a simple, robust, and relevant metric for measuring skin dose in breast brachytherapy.

METHODS AND MATERIALS: Postoperative treatment plans (Day 0) for 15 permanent breast seed implant (PBSI) and 10 multicatheter high-dose-rate (MC-HDR) brachytherapy patients were included. Retrospectively, three skin structures were contoured: 2 mm external from the body; and subsurface layers 2 mm and 4 mm thick. Maximum point dose (D_{max}), doses to small volumes (e.g., $D_{0.2cc}$), and the volumes receiving a percentage of the prescription dose ($V_{\%}$, e.g., V_{66}) were calculated. $D_{0.2cc}$ was investigated as a surrogate to the dose given to 1 cm^2 of skin (D_{1cm^2}). Pearson product–moment correlation (R^2) was computed between metrics.

RESULTS: Observed trends were consistent across brachytherapy technique. $V_{\%}$ did not correlate well with any other metrics: median (range) R^2, 0.63 (0.43, 0.77) and 0.69 (0.3, 0.89) for PBSI and MC-HDR, respectively. D_{max} was inconsistently correlated across contours and not well correlated with doses to small volumes: median (range) R^2, 0.85 (0.76, 0.93) and 0.88 (0.83, 0.93) for PBSI and MC-HDR, respectively. In contrast, doses to small volumes were consistently well correlated, even across skin layers: $D_{0.1cc}$ vs. $D_{0.2cc}$ median (range) R^2, 0.98 (0.97, 0.99) and 0.97 (0.94, 0.99) for PBSI and MC-HDR, respectively.

CONCLUSIONS: Doses to small volumes are robust measures of breast skin dose and given skin's strong area effect, $D_{0.2cc}$ for a 2 mm thick skin layer, a simple surrogate of D_{1cm^2}, is recommended for recording skin dose in any breast brachytherapy. D_{max} is not robust and should be avoided.

Keywords: Breast brachytherapy; Breast permanent seed implants; HDR brachytherapy; Postoperative; Dosimetry; Skin dose; Skin toxicity

Introduction

Breast-conserving therapy, including lumpectomy followed by adjuvant radiation therapy (RT) to the whole breast, is the standard of care of early-stage breast cancer as it has been shown equivalent to mastectomy in terms of disease-free and overall survival but offers significantly improved cosmetic outcomes (1, 2). Ensuring an excellent cosmetic outcome is paramount in treatment of the breast, and skin is a primary critical structure for breast RT. This study aims to provide guidance in defining an appropriate metric for measuring skin dose in breast brachytherapy. A lack of consistency in metrics currently used to record skin dose in breast brachytherapy may compromise our ability to define meaningful breast skin dose limits critical for quality breast brachytherapy.

Breast brachytherapy is gaining momentum as a form of accelerated partial breast irradiation (APBI). APBI, an alternative to whole-breast irradiation (WBI) for adjuvant RT after breast-conserving surgery, treats the lumpectomy site with a margin and is usually completed within 1 week (3, 4). This accelerated treatment schedule, when compared with conventional treatment regimens of 3–4 weeks (Canada) or up to 7 weeks (United States), is both attractive to patients and resource efficient and is one of the primary motivations for APBI. APBI can be achieved using external beam RT, brachytherapy, or intraoperative therapy(3–6);

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* Corresponding author. Medical Physics, BC Cancer Agency, Sindi Ahluwalia Hawkins Centre for the Southern Interior, 399 Royal Avenue, Kelowna, British Columbia V1Y 5L3, Canada. Tel.: +250-712-3966×686738; fax: ±250-712-3911.

E-mail address: mhilts@bccancer.bc.ca (M. Hilts).

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this work focuses on brachytherapy-based APBI. There are several established approaches to using brachytherapy for APBI (4, 7). High-dose-rate (HDR) brachytherapy is currently the most common type of APBI and can be performed using several different treatment techniques: multicatheter interstitial implants, intracavitary implants using a single or a multichannel balloon device, or intracavitary implants using a multichannel strut-based device (7). Recently, low-dose-rate permanent breast seed implants (PBSI) have also been introduced as a technique for both breast boost treatment (8, 9) and as APBI (10–16).

Multiple clinical trials have established the safety and efficacy of brachytherapy-based APBI (4). Recently reported outcomes from a phase III randomized trial showed comparable tumor control between APBI using brachytherapy and standard WBI, while providing improved cosmetic outcomes in the brachytherapy arm (17). As with all breast radiation techniques, the skin is an important organ at risk for which dose-related skin toxicity can adversely affect cosmetic outcomes (18). When compared with WBI, where the entire breast skin surface is included in the treatment volume, the use of APBI reduces the total volume of irradiated breast skin. APBI can, however, produce localized high doses close to the skin that may result in skin toxicity, including moist desquamation and telangiectasia. Monitoring and limiting the skin dose is an important consideration when undertaking quality APBI (4, 12, 18). Historically, a minimum distance from implant to skin was used as a surrogate for skin dose (18–23). More recently, Radiotherapy and Oncology Group (RTOG) trial guidelines have recommended keeping the maximum point dose (D_{max}) to the skin surface below 145% and 100% of the prescription dose for balloon and interstitial plans, respectively (6). In the American Brachytherapy Society (ABS) consensus statement, Shah *et al.* (4) recommended recording and limiting D_{max} at the skin surface for APBI brachytherapy. Many recent breast brachytherapy studies have included reports of D_{max} at skin surface in their postimplant dosimetry (10,18,24–28).

While a better definition compared to the prior distance-based surrogate metric for skin dose, the choice of D_{max} at skin surface is not ideal for several reasons. First, a point dose is not a robust measure of dose as it may be subject to variability due to dose voxelization and contour uncertainties. Second, dose to the skin surface is not the most relevant metric for skin toxicity as evidence suggests that it is radiation damage to the underlying skin layers rather than the skin surface that leads to observed skin toxicity (29,30). Furthermore, skin is known to exhibit an area effect in response to radiation (31), rendering the importance of a maximum point dose questionable at best. Although D_{max} at skin surface is a simple metric to compute, an ideal metric should be not only simple, but also robust and relevant.

The need for a better skin dose metric has been recognized in breast brachytherapy as a number of authors have recently used alternate metrics in their publications (8, 12, 13, 24–26). These alternate metrics have included: D_{max} for subsurface layers of skin (8, 24); doses to small volumes (0.1–1.0 cc) at the skin surface and for subsurface rinds of skin (2 mm and 4–5 mm thicknesses) (8, 24, 26, 32); volumes of a 4–5 mm thick rind of subsurface skin receiving a given percentage of the prescription dose (8); and the dose to the hottest 1 cm^2 area at skin surface (12,13). In addition, authors have used a range of skin structures based on external body contour expansions (typically 5–10 mm) as a tool to calculate the ABS recommended D_{max} to skin surface (20,24,33). The substantial variety of skin dose metrics in the literature leads to confusion as to how best to measure skin dose, how to compare recorded doses, and how to relate calculated doses to any available recommended dose limits. If the different metrics were to predict for one another in a simple linear fashion (i.e., linearly correlate), it would be possible to easily relate them; one metric could simply be scaled to match the other. However, if these different metrics do not correlate with one another, comparison of recorded skin dose across studies using different metrics would prove challenging. In this scenario, the potential impact is serious as the use of a variety of metrics could ultimately undermine our ability to establish meaningful relationships between skin dose and toxicity, relationships that are required for guidance of clinical practice in breast brachytherapy. The best solution would be to adopt a single simple, robust, and relevant metric for measuring skin dose.

In this study, we aim to determine the correlation between the available metrics in the literature for measuring skin dose and to define a simple, robust, and relevant metric for future use: $D_{0.2cc}$ for a 2 mm thick subsurface layer of skin. Skin dose resulting from two distinct APBI brachytherapy techniques are included: multicatheter high-dose-rate (MC-HDR) brachytherapy and PBSI.

Methods and Materials

Breast brachytherapy techniques

Postimplant imaging for 15 patients who received PBSI and for 10 patients who received MC-HDR breast brachytherapy at our center was included. Both MC-HDR and PBSI breast brachytherapy treatments are offered to eligible patients with low-risk breast cancer participating in trials to establish the feasibility of these breast brachytherapy techniques at our center. PBSI patient eligibility criteria were age >60 years, Stage 0 or 1 breast cancer resected with lumpectomy, clear margins, no evidence of metastatic disease, and seroma up to 3 cm in diameter. MC-HDR had moderately expanded eligibility to include patients >50 years and those with Stage II disease with seroma up to 3 cm in diameter. Technical eligibility criteria for both techniques included size, visibility, and location of the seroma. Details of both the MC-HDR and PBSI treatment techniques used are provided below.