ELSEVIER

Brachytherapy ■ (2018) ■

BRACHYTHERAPY

Appropriate timing for postimplant imaging in permanent breast seed implant: Results from a serial CT study

Elizabeth Watt[1,2,*], Leigh Conroy[1,2], Michael Peacock[3], Michael Roumeliotis[1,2,4], Amy Frederick[1,2], Siraj Husain[4,5], Tyler Meyer[1,2,4]

[1]*Department of Physics & Astronomy, University of Calgary, Calgary, AB, Canada*
[2]*Department of Medical Physics, Tom Baker Cancer Centre, Calgary, AB, Canada*
[3]*Division of Radiation Oncology, University of British Columbia, Vancouver, BC, Canada*
[4]*Department of Oncology, University of Calgary, Calgary, AB, Canada*
[5]*Department of Radiation Oncology, Tom Baker Cancer Centre, Calgary, AB, Canada*

ABSTRACT

PURPOSE: Postimplant analysis in permanent breast seed implant (PBSI) is performed at inconsistent times subsequent to seed implantation across cancer centers, creating challenges in the interpretation of dosimetric data and ultimately the correlation with clinical outcomes. The purpose of this study is to determine the most appropriate time postimplant to perform this analysis.

METHODS AND MATERIALS: Nine patients treated at our institution with PBSI were included in this analysis. Each underwent 4 postimplant CT scans: 0, 15, 30, and 60 days postimplant. A model of the accumulated dose was created by deformably registering the Day 15, 30, and 60 postimplant CT scans and dose matrices to the Day 0 scan, scaling for seed decay. The results from this model were compared to each individual postplan by integral comparison of dose−volume histogram curves for a dose evaluation volume.

RESULTS: The Day 30 postplan showed the best agreement with the accumulated dose model and the smallest interpatient variability across the patient cohort. The mean (±SD) for the dose evaluation volume V_{90}, V_{100}, V_{150}, and V_{200} for the accumulated dose model was 90 ± 7%, 86 ± 8%, 66 ± 14%, and 41 ± 16%, respectively.

CONCLUSIONS: Based on the results of this patient cohort, we recommend that postimplant dosimetric analysis for PBSI be performed approximately 30 days following the implant.

Keywords: Permanent breast seed implant; Deformable image registration; Dose accumulation; Serial imaging

Introduction

The standard-of-care for early-stage breast cancer has been established as whole-breast irradiation following lumpectomy. In recent years, however, various external beam and brachytherapy modalities have been applied to partial-breast irradiation. This is motivated by research demonstrating that most recurrences occur close to the original tumor site (1). Select patients may therefore be candidates to receive postlumpectomy radiation only to this region, expanded by an appropriate margin. Partial-breast irradiation has been in clinical use for several decades as an afterloader-based high-dose-rate brachytherapy technique (2). Excellent results have been achieved in long-term Phase III clinical trials for multicatheter interstitial high-dose-rate brachytherapy (3, 4). Permanent breast seed implant (PBSI) (5, 6) is an innovative treatment technique for partial-breast irradiation using low-dose-rate sources. This procedure offers patients an attractive alternative to standard fractionated external beam radiotherapy by condensing the radiation timeline to a 1-day outpatient procedure.

As a burgeoning technique, inconsistencies remain in clinical PBSI practice between centers; of particular importance is the timing of postimplant dosimetry. Imaging is currently performed at varying time points subsequent to the implant at different centers. Two months postimplant

Received 14 November 2017; received in revised form 16 January 2018; accepted 16 January 2018.

Conflict of interest: The authors have no conflicts of interest to disclose.

* Corresponding author. Department of Medical Physics, Tom Baker Cancer Centre, 1331 − 29 St NW, Calgary, AB, T2N 4N2, Canada. Tel.: +1-403-521-3792.

E-mail address: elizabeth.watt@ahs.ca (E. Watt).

1538-4721/$ - see front matter
https://doi.org/10.1016/j.brachy.2018.01.006

was initially suggested as an appropriate time to perform this analysis (7) as seed migration was hypothesized to be at a maximum. Some centers, however, perform postimplant analysis sooner after the procedure (8, 9).

The timing of postimplant analysis for permanent prostate brachytherapy was explored several decades ago during the development of that technique. The AAPM TG-137 report (10) summarizes recommendations on appropriate postimplant timing for prostate brachytherapy performed with ^{125}I, ^{103}Pd, and ^{131}Cs. These recommendations have helped to standardize the technique and increase consistency in reporting dosimetric results.

The lack of consistency in postimplant analysis timing in PBSI creates challenges in the amalgamation of data from different centers toward the ultimate goal of correlating outcomes with relevant dosimetric indices. The purpose of this study is to determine an appropriate time subsequent to seed implantation to perform postimplant CT imaging and analysis, based on the imaging time point that best corresponds to the total deposited dose over the life of the seeds.

Methods and materials

Patient selection

Ten consecutive patients treated with PBSI at our institution between July 2015 and July 2016 were considered for inclusion in this study. Patients first underwent breast-conserving surgery and were screened for eligibility according to our institutional protocol, including confirmation of seroma visibility under both CT and ultrasound imaging and low-risk characteristics (following many of the GEC-ESTRO recommendations (11)). All patients provided informed consent to be included in this study. During analysis, 1 patient was excluded from the study due to anatomical variations postimplant rendering deformable image registration infeasible.

Patients underwent a planning CT scan in the supine position with their ipsilateral arm abducted above their head, matching their implant orientation. The radiation oncologist contoured the clinical target volume (CTV; seroma) and the chest wall muscle on this scan. The planning target volume (PTV) was defined as a 10-mm isotropic expansion of the CTV, trimmed to the chest wall muscle and a 5-mm skin rind. Seed positions were forward-planned using the MIM Symphony treatment planning system (MIM Software, Inc., Cleveland, OH) to a prescription dose of 90 Gy. Planning goals included CTV $V_{100} \geq 99.9\%$ and PTV V_{100} and $V_{200} \geq 95\%$ and $\leq 40\%$, respectively. Implants were performed using stranded ^{103}Pd seeds (Advantage; IsoAid, Port Richey, FL).

Postimplant imaging and analysis

Patients underwent postimplant CT scans in the same position as the treatment planning CT scan (12), nominally scheduled at 4 intervals: 0 (immediately after), 15, 30, and 60 days after seed implantation. Imaging parameters for patients at our center include 120 kV, 299 mAs, 512 × 512 in-plane pixels, 2-mm slice thickness, and 459 to 654-mm field of view. Standard postplans were completed on each of these images. The postplan process closely follows that described by Hilts *et al.* (8). In brief, using MIM Maestro, the planning CT was deformably registered to each postimplant scan to transfer the CTV and chest wall muscle contours. All deformed structures were reviewed by the same radiation oncologist and adjusted where necessary. These adjustments were quantified using the Dice similarity coefficient (DSC) (13). A dose evaluation volume (DEV) was defined on each postimplant CT scan as a 5-mm isotropic expansion of the CTV contour for that time point, trimmed to the chest wall muscle and the skin. All seeds were identified on each of the 4 postimplant scans and dose was calculated using the line-source approximation of the TG-43 formalism (14).

Dosimetric analysis

A model of the accumulated dose was created by deformably registering the Day 15, 30, and 60 scans, along with their associated dose matrices, to the Day 0 scan using the Velocity Structure-Guided Deformation Navigator (Varian Medical Systems, Palo Alto, CA). First, the proximal ribs and ipsilateral chest wall muscle were aligned using manual rigid registration. For the subsequent deformable registration, the region-of-interest was defined to encompass a 34-mm expansion of the CTV contour. This expansion was selected based on our clinical practice of planning seed placement up to 10 mm outside of the CTV and previously reported PBSI seed placement accuracy of 9 ± 5 mm (15) (i.e., 34 mm encompasses the 10-mm expansion + 9-mm mean seed placement accuracy + 3σ [15 mm] for variance in seed placement accuracy). As a verification of the quality of this deformation, the CTV contours were deformed with their respective scans and compared to the original Day 0 contour qualitatively and quantitatively using the DSC. A simplified example of this process for 1 patient is shown in Fig. 1.

Each dose matrix was calculated on the relevant postimplant CT scan using the line-source approximation of the TG-43 formalism (14) (as discussed in the section Postimplant imaging and analysis). This dose matrix was then deformed to the Day 0 scan and scaled to account for seed decay before dose summation. This scaling took into account the patient-specific differences in scan timing. Dose scaling was accomplished by considering the cumulative dose delivered by a permanent implant:

$$D_c = \frac{\tau_{1/2}}{\ln 2}\,\dot{D}_0$$

where D_c is the cumulative dose [Gy], $\tau_{1/2}$ is the radionuclide half-life [d], and $\dot{D}_0$ is the initial dose rate [Gy/d].