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Optimization and comparison of balloon-based partial breast brachytherapy using a single source, a standard plan line source, and both forward and inverse planned multilumen techniques

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ABSTRACT

PURPOSE: This study directly compares four dosimetric techniques for balloon-based partial breast brachytherapy: single source, standard line source, and both forward planned and inverse planned multilumen (ML). A standard line source plan is presented to be used in a single catheter or as a starting point for forward planned ML.

METHODS AND MATERIALS: The study population consists of 12 patients previously treated with a single lumen. Inverse plans were created for 7 patients and used to create a standard line source plan. ML plans were created on the same patient data sets. The dosimetric aims were as follows: PTV_EVAL (planning target volume for evaluation) D_{95} (dose received [%] by 95% of PTV_EVAL volume) $\geq 95\%$ of the prescribed dose (PD), the maximum skin and rib dose $\leq 125\%$ of prescription dose, breast V_{150} (volume [cc] receiving 150% of the PD) ≤ 50 cc, and V_{200} (volume [cc] receiving 200% of the PD) ≤ 10 cc.

RESULTS: The number of patients fulfilling all dosimetric constraints went from 1 patient of 12 with a single catheter to 6 patients of 12 with inverse planned ML and 7 patients of 12 with forward planned ML. PTV_EVAL D_{95} increased significantly with the standard line source plans and ML plans when compared with the single-source plans. Forward planning took, on average, 7 min longer than inverse planning.

CONCLUSION: Multiple sources in a single catheter improve coverage at catheter ends, whereas ML can further improve coverage and reduce dose to organs at risk. Using a standard line source as a starting point for forward planning ML means increase in planning time is kept to a minimum, making it a practicable option for centers without inverse planning software. Patients previously ineligible for treatment with a single catheter may be treated using ML.

Keywords: MammoSite; Accelerated partial breast irradiation; Brachytherapy; Breast cancer; Inverse planning

Introduction

Whole breast irradiation (WBI) after breast conserving surgery improves local control and overall survival but exposes large volumes of normal tissue including heart and lung to high doses that may result in late adverse effects (1). Partial breast irradiation (PBI) has been explored as an alternative because studies suggest that microscopic disease usually extends 1–2 cm beyond the surgical cavity (2) and most of the local recurrences are located close to the area of surgical resection/index quadrant. The local recurrences outside the index quadrant are often new primary and do not seem to be affected significantly by the use of WBI (3).

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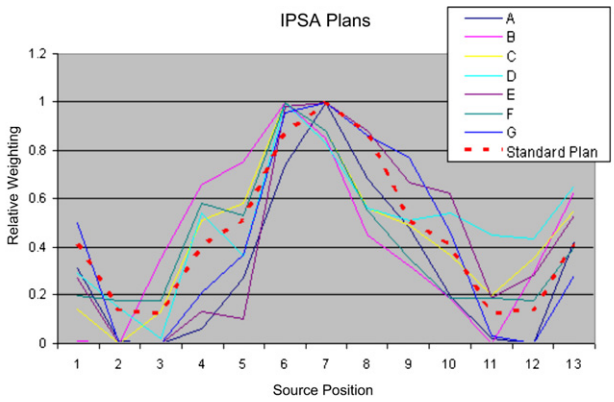
PBI targets the tumor bed (area at the highest risk of relapse), sparing more distant tissue from high dose, with the intention of reducing normal tissue side effects and maintaining local control. Multi-catheter–based interstitial brachytherapy has been used for many years but its relative complexity limits its use to a few centers (4). MammoSite (Hologic, Inc., Bedford, MA) brachytherapy (MSB) has been introduced as a simple implantation, treatment planning and delivery method for PBI. The catheter has been previously described in detail (5). Although simple and quick to plan, this method has some substantial dosimetric drawbacks:

1. Failure to compensate for the anisotropy of the ^{192}Ir source;
2. Balloon asymmetry greater than 2 mm leads to unacceptable asymmetric planning target volume (PTV) coverage and these patients are usually not eligible for MSB (6);
3. The dose to the skin and ribs are determined solely by their position relative to the MSB device and the only option to reduce dose to the organs at risk (OARs) is by reducing the prescription dose and hence the target dose. Previous studies (7–9) suggest that increased toxicity may occur when skin gets greater than 125% of the prescribed dose (PD) and patients are often ineligible for MSB if the balloon-to-skin distance is <7 mm (6).

To address some of these issues, the multilumen MammoSite (ML-MS) catheter was developed. It provides a central catheter and three outer catheters, each 3 mm from the central catheter with 120° separation. It therefore enables a greater flexibility in dose optimization, with the ability to load outer catheters to compensate for balloon asymmetry and shift isodoses to avoid OARs. However, there is no current standard approach to efficiently produce individualized loading patterns.



Standard Plan Relative Weightings:

Source Position	1&13	2&12	3&11	4&10	5&9	6&8	7
Relative Weighting	0.40	0.15	0.14	0.41	0.51	0.87	1.0

Fig. 1. Results of inverse planning simulated annealing (IPSA) on 7 patients and the subsequent standard plan. Weightings for the standard line source plan are shown.

This dosimetric study aimed to develop a standard line source-loading pattern for the single-lumen catheter to test if (*1*) dosimetry is improved compared with a single source and (*2*) it can be used as an efficient starting point to produce individualized forward plan for the ML catheter. These forward planned ML solutions are compared with inverse planned ML solutions to see if forward planning is a practicable option. This unique study enabled direct comparison between the dosimetric capabilities of the single-lumen and ML-MS catheters by using the same patient cohort. Previous studies comparing single-lumen and ML balloon catheters were carried out on different patient cohorts and

Table 1
Dosimetric characteristics of PTV coverage for the four different planning techniques

			Single source				Standard plan (single lumen)		
Patient	Skin-to-balloon distance (mm)	Asymmetry (mm)	D_{95} (%)	V_{200} (cc)	DHI	FWHM (cGy per #)	D_{95} (%)	V_{200} (cc)	DHI
A	15	<2	86.0	2.6	0.71	162	93.3	6.3	0.66
B	10	7	83.6	3.6	0.70	173	92.9	6.6	0.64
C	16	5	88.0	5.2	0.65	189	97.1	9.3	0.58
D	7	2.3	83.7	3.0	0.65	213	95.0	6.1	0.59
E	9	3.5	86.1	5.0	0.65	215	96.9	8.1	0.57
F	21	6	79.9	3.9	0.70	225	86.3	7.4	0.63
G	7	<2	92.6	1.9	0.68	205	101.5	7.0	0.60
H	9	<2	88.5	1.4	0.72	202	97.4	4.6	0.66
I	39	2.5	99.2	4.2	0.67	177	106.2	10.0	0.60
J	18	2.5	92.4	4.0	0.66	190	102.0	8.9	0.60
K	6	3.5	94.7	5.5	0.60	257	101.9	8.9	0.55
L	8	2	88.7	4.9	0.60	225	99.4	8.0	0.56
Average			88.6	3.8	0.67	203	97.5	7.6	0.60

PTV = planning target volume; DHI = dose homogeneity index; FWHM = feasibility of breast radiotherapy using MammoSite; D_{95} = dose received (%) by 95% of PTV_EVAL volume; V_{200} = volume (cc) receiving 200% of the prescribed dose.