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Strut-based accelerated partial breast irradiation: Report of treatment results for 250 consecutive patients at 5 years from a multicenter retrospective study

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ABSTRACT

PURPOSE: This registry trial studied the long-term outcomes of women receiving accelerated partial breast irradiation (APBI) using strut-based applicators and reports on the local control, toxicity, and survival for the first 250 patients treated with this device.

METHODS AND MATERIALS: Patients were treated using the strut-based brachytherapy device with conventional dose and fractionation of 34 Gy in 10 twice-daily fractions. Planning goals for the planning target volume were $V_{90} > 90\%$, $V_{150} < 50$ cc, and $V_{200} < 20$ cc. Toxicity was graded based on the Common Terminology Criteria for Adverse Events v3.0. Recurrence rates were also calculated.

RESULTS: Median followup was 59.5 months for the 250 patients. Grade 2 or higher adverse events at any time for hyperpigmentation, induration, erythema, telangiectasia, breast pain, seroma, and fat necrosis were 0.4%, 3.0%, 3.0%, 3.0%, 3.9%, 4.8%, and 1.3%, respectively. The median V_{90} was 97%, V_{95} was 95.1%, V_{150} was 28.7 cc, and V_{200} was 14.2 cc. For those patients with a less than a 5-mm or 3-mm-skin bridge, the median skin max doses were 272 and 289 cGy, respectively. The 4-year actuarial recurrence rates for true recurrence/marginal miss and ipsilateral breast tumor recurrence were 2.3% and 3.6%, respectively. The 4-year actuarial rates for overall survival, cause-specific survival, and disease-free survival were 97%, 98%, and 92%, respectively.

CONCLUSIONS: The strut-based applicator was designed to simplify APBI compared to interstitial brachytherapy. This report confirms excellent tumor control and survival with low toxicity and supports the evidence that brachytherapy has less normal tissue toxicity than APBI with external beam irradiation. © 2016 Published by Elsevier Inc. on behalf of American Brachytherapy Society.

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Breast brachytherapy; APBI; Brachytherapy; SAVI; Strut based; Strut; Balloon based; Multilumen; Interstitial; Breast conservation

Introduction

Accelerated partial breast irradiation (APBI) has emerged as an acceptable modality for delivering adjuvant radiation therapy for a selected group of patients undergoing breast-conserving therapy. The recently published GEC-ESTRO trial, a Phase III randomized prospective trial, demonstrated the noninferiority of APBI with brachytherapy in comparison to whole breast irradiation (WBI) (1). Several additional APBI studies have also published results demonstrating local control that is equivalent to WBI with 5 years and 10 years of followup (2–7). Originally, patients were treated with multicatheter interstitial therapy, and updated interstitial data reveal outstanding outcomes (8, 9). With the introduction of single-entry devices, the use of APBI accelerated as multicatheter interstitial brachytherapy is highly skill dependent and not easily reproducible (10–14). Single-entry intracavitary devices, like the MammoSite balloon, improved ease of use, but early experience showed that because of the inability to dosimetrically modulate dose, inadequate skin and chest wall spacing led to significantly increased toxicity (10, 15–18). The introduction of multilumen catheter devices allowed the radiation dose cloud to be sculpted to the woman's anatomy more precisely and increased the number of women eligible for APBI (19, 20). In addition to multicatheter and single-entry devices, external beam APBI using photons or protons is also described in the literature (21, 22).

The device reported in this trial has a fixed central catheter and additional peripheral source lumens that are expanded to be in direct contact with the surgical margin and comes in four sizes (6-1Mini, 6-1, 8-1, and 10-1) with 6, 8, or 10 peripheral struts and 1 central strut. This paper reports on the local control, toxicity, and survival for the first 250 patients treated across multiple institutions with the strut-based device (Strut Adjusted Volume Implant; Cianna Medical, Aliso Viejo, CA).

Methods and materials

Study participants

In the late 2010, a consortium of 11 institutions began an IRB-approved retrospective study of consecutively treated APBI patients treated with the Strut Adjusted Volume Implant device before December 31, 2010. The earliest patient included in this study completed brachytherapy in the late 2007. All subjects in this analysis received monotherapy.

A total of 250 patients are included in the analysis. This cohort of patients is the first 250 accrued into the study, with no other inclusion/exclusion requirements other than having been accrued into the registry study (e.g., no requirement for minimum amount of followup, reported values for treatment variables, etc.). From this group of subjects, descriptive statistical analyses were conducted on the patient characteristics, toxicity, and local control.

Treatment

The device was placed within the lumpectomy cavity either at the time of surgery or postoperatively under ultrasound guidance once the patient's eligibility for treatment had been pathologically confirmed. The multiple device sizes allowed the accommodation of a wide range of cavity sizes. Following applicator placement, patients underwent CT-based simulation for treatment planning to delineate the cavity, treatment volume, skin, and ribs. Treatment plans were generated to deliver a prescription dose of 34 Gy to the PTV-Eval in 10 twice-daily fractions of 3.4 Gy each, with a minimum of 6 hours between treatments. The planning treatment volume (PTV) was defined as a 1-cm expansion from the cavity edge. The PTV-Eval was the PTV minus chestwall, cavity, and the subcutaneous tissue 5 mm below the skin surface. Invaginated tissue, when present, was added to the PTV-Eval to insure all treated tissue was evaluated for coverage and V_{150} and V_{200} vol limitations (V_{150} and V_{200} defined as the volume of tissue receiving 150% and 200% of the prescription dose, respectively). The typical planning for this applicator entailed optimizing the outer surface of the PTV-Eval to 100% of the prescribed dose, including portions of that surface that are less than 1.0 cm in thickness due to thin skin bridges or close proximity to the ribs as shown in Fig. 1. The open architecture allowed the peripheral lumens (6, 8, or 10) to be in direct juxtaposition to the target tissue. Thus, one goal of the planning was to limit the dose to the skin and chestwall to 100% of the prescribed dose as much as possible.

It is noted that some treating centers may have used an internal 2- to 3-mm-skin margin for optimizing skin doses. Additionally, some centers exclude only ribcage, whereas others exclude pectoralis from the optimization. Dosimetric goals included a $D_{90} \geq 90\%$ of the prescription dose, $V_{150} \leq 50$ cc, and $V_{200} \leq 20$ cc, skin dose $\leq 100\%$, and these values were collected from each treatment site as well as PTV-Eval in cc and rib dose (23). D_{90} is defined as the prescription dose delivered to 90% of the target, PTV-Eval.

Toxicity

Toxicity was graded according to the Common Terminology Criteria for Adverse Events version 3.0 except

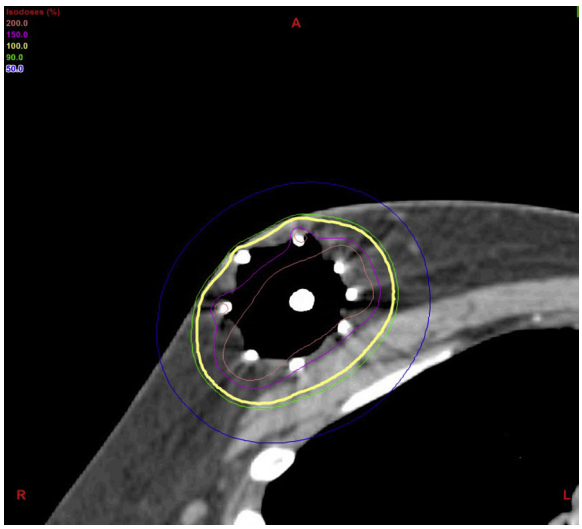

Fig. 1. SAVI 8-1 inserted into right breast. The yellow line represents the 100% isodose line. Note the small skin bridge and the ability to sculpt the isodose lines to avoid overdosing the skin.

seroma and fat necrosis, which were modified by the consortium to more appropriately fit APBI as shown in Table 1. Early toxicities were those that seemed from placement until 6 weeks and late effects from 6 weeks onward.

Each site graded toxicity according to a standardized, structured form, and these forms were sent at 6 weeks and every 6 months until study closure to data collection. Data collected included disease status, recurrence and whether true recurrence/marginal miss (TR/MM) or elsewhere and histology of recurrence, contralateral recurrence, regional recurrence, DM, date of last mammogram/ultrasound/magnetic resonance imaging with free text for positive findings, cosmesis score, hormonal therapy, and grading of late effects including hyperpigmentation, induration, erythema, telangiectasias, fibrosis, breast pain, seroma, fat necrosis, breast asymmetry and cause (surgical or radiation), and other toxicities as a write-in. Cosmesis was graded excellent, good, fair, and poor according to the Harvard scale (24). Of note, in some centers, ultrasound was routinely done, and fat necrosis or seroma was routinely indicated on followup mammograms, but in others, changes expected after lumpectomy with or without radiation were simply reported as "postlumpectomy changes." This difference prompted the modification of the grading of seroma and fat necrosis as per the included table to represent those that were symptomatic.

Statistics

Recurrence rates were computed as crude and 4-year actuarial rates for breast only (ipsilateral breast tumor recurrence [IBTR]), TR/MM, ipsilateral elsewhere (>2 cm from index lesion), contralateral breast, regional only (solely in the axilla and supraclavicular nodes), and distant. True recurrence is defined as recurrence at the original site of the primary. Marginal miss is defined as recurrence at the edge of the treated volume and elsewhere recurrence is outside these defined volumes (25). Univariate analyses were done to look for associations between dosimetric variables and acute and late toxicities. For dichotomous variables, the Fisher's exact test was used, and for continuous variables, logistic regression was used to look for statistically significant associations between acute and late toxicities and dosimetric characteristics. Statistics were calculated using version 9.3 of the SAS statistical software package. With the low number of events, true statistical significance may need p-Values < 0.0001.

Results

Patient characteristics

The group of 250 patients is described statistically in Table 2. Out of the 250 patients, 73.5% had invasive disease and the remaining 26.5% had pure ductal carcinoma *in situ*. The median age was 62 years (range, 40−85). The majority (57%) of these women were over 60 years old, although 36 (14.4%) were <50 years (11 were <45 years). Most patients were postmenopausal (84%), had estrogen receptor positive tumors (90%), received endocrine therapy (65%), and did not receive chemotherapy (91%).

Table 1
Toxicity definitions

Toxicity (CTCAE version 3.0)	Grade 2
Hyperpigmentation	Slight or localized
Induration	Marked increase in density and firmness on palpation with or without minimal retraction
Telangiectasias	Moderate number
Breast pain	Moderate, pain, or analgesics interfering with function, but not ADL

Toxicity (modified from CTCAE version 3.0)	Grade 0	Grade 1	Grade 2	Grade 3
Seroma	Not mentioned or not present	Radiographic or clinical but asymptomatic	Symptomatic	Aspirated or excised for symptoms
Fat necrosis	Not mentioned or not present	Radiographic or clinical but asymptomatic	Symptomatic	Aspirated or excised for symptoms

ADL = activities of daily living; CTCAE = Common Terminology Criteria for Adverse Events.

Table 2
Patient characteristics

Characteristic	All cases
Subjects	250
Breasts	250
Age	
Median (range) (years)	62 (40,85)
>60 years, *N* (%)	142 (56.8%)
>50−<60 years, *N* (%)	72 (28.8%)
>45−<50 years, *N* (%)	25 (10.0%)
<45 years, *N* (%)	11 (4.4%)
Menopausal status, *N* (%)	
Premenopausal	31 (13.0%)
Perimenopausal	7 (2.9%)
Postmenopausal	201 (84.1%)
Tumor size (mm)	
Median (range)	11.0 (0,55)
<5	29 (11.8%)
>5−<10	70 (28.6%)
>10−<20	100 (40.8%)
>20−<30	31 (12.7%)
>30	5 (2.0%)
AJCC tumor status, *N* (%)	
Tis	60 (26.5%)
T1A	20 (8.8%)
T1B	55 (24.3%)
T1C	69 (30.5%)
T2	22 (9.7%)
AJCC nodal status, *N* (%)	
N0	220 (91.7%)
NX	16 (6.7%)
N(+)	4 (1.7%)
Margins, *N* (%)	
Negative	230 (97.9%)
Positive	2 (0.9%)
Close A (≤1 mm)	3 (1.3%)
Close B (>1 mm−≤2 mm)	0 (0%)
Estrogen receptor status, *N* (%)	
Positive	218 (89.7%)
Negative	25 (10.3%)
Last followup (months)—all breasts (time since RT Stop)	
N	236
Median	59.5
Mean (SD)	54.6 (18.5%)
Range	0.5−84.1

AJCC = American Joint Committee on Cancer; SD = standard deviation; RT = radiation therapy.

Margin status was available for 235 patients (Table 2). In these patients, margins were negative in 98%, close (<1 mm) in 3 (1.3%), and positive in 2 (0.9%).

Tumor size was reported in 94% of subjects with 85% of patients having pathologic tumor sizes in the range of 1−20 mm (2% were >30 mm). Table 2 provides the full breakdown of tumor size distribution.

Median followup in these patients was 59.5 months. Of this group, 80% had ≥3 years of followup and 70% had ≥4 years of followup.

Dosimetry

For the 250 patients, the mean V_{90} was 96.1 ± 3.7%, V_{95} was 93.5 ± 6.1%, V_{150} was 30.5 ± 11.0 cc, and V_{200} was 14.7 ± 5.1 cc. These dosimetric variables differed by device. Table 3 lists the achieved dosimetric values by device size. Skin dose mean was 269 cGy (79.1% of prescription dose). For those patients with a skin bridge >3 mm and ≤5 mm or ≤3 mm, the mean values were 274 cGy and 281 cGy (80.7 and 82.7% of the prescription dose), respectively. The mean rib dose was 273 cGy (80.4% of the prescription dose).

Applicator

In this cohort, all four sizes of applicator were used: 10-1 (21%), 8-1 (32%), 6-1 (38%), and 9% received the 6-1 Mini size.

Skin spacing

More than half the patients had skin spacing less than or equal to 10 mm (44% > 10 mm) with 12% and 17% having skin bridges of 3−5 mm and ≤3 mm, respectively.

Toxicity

Grade 2 or higher adverse events at any time for hyperpigmentation, induration, erythema, telangiectasia, breast pain, symptomatic seroma, and symptomatic fat necrosis were 0.4%, 3.0%, 3.5%, 3.0%, 3.9%, 4.8%, and 1.3%, respectively. Time course of toxicity is shown in Table 4. Infection rate was 3.7%, with some centers giving prophylactic antibiotics. There was no statistically significant associations on univariate analysis for acute effects. For late effects on univariate analysis, there were marginal associations between PTV-Eval ($p = 0.0155$), V_{150} ($p = 0.0250$),

Table 3
Dosimetry

		N mean (std)							
Clinical scenarios	*N*	Skin dose % PD	Rib dose % PD	PTV-Eval (cc)	V_{90} (% PTV-Eval)	V_{95} (% PTV-Eval)	V_{100} (% PTV-Eval)	V_{150} (cc)	V_{200} (cc)
All subjects	250	79.1 (27.16)	80.4 (37.24)	71.6 (27.96)	96.1 (3.74)	93.5 (6.13)	90.4 (5.50)	30.5 (11.03)	14.7 (5.11)
Device									
10-1	52	74.0 (30.28)	76.1 (33.19)	107.1 (23.52)	95.9 (4.82)	92.7 (6.81)	89.3 (6.43)	43.0 (11.31)	18.0 (5.32)
8-1	80	77.6 (19.51)	92.6 (39.25)	74.5 (20.32)	96.5 (3.12)	94.4 (4.42)	90.6 (4.74)	31.8 (7.84)	14.9 (4.25)
6-1	96	79.8 (30.63)	71.1 (35.73)	54.9 (15.52)	95.8 (3.67)	92.7 (7.28)	90.7 (5.59)	24.9 (8.28)	13.0 (5.07)
6-1 Mini	22	91.3 (26.20)	82.3 (38.67)	50.0 (15.73)	96.9 (3.20)	94.8 (4.28)	91.6 (5.25)	22.9 (4.34)	12.8 (3.49)

PD = prescription dose.

Table 4
Toxicity onset at any time

Toxicity (≥Grade 2)	At any time, *N* (%)	0–12 Months	>12–18 Months	>18–24 Months	>24 Months
Subjects at risk	230	230	220	217	214
Hyperpigmentation	1 (0.4%)	0 (0%)	0 (0%)	0 (0%)	1 (0.5%)
Induration	7 (3.0%)	2 (0.9%)	0 (0%)	1 (0.5%)	4 (1.9%)
Erythema	8 (3.5%)	6 (2.6%)	0 (0%)	0 (0%)	2 (0.9%)
Telangiectasia	7 (3.0%)	0 (0%)	1 (0.5%)	0 (0%)	6 (2.8%)
Breast pain	9 (3.9%)	3 (1.3%)	1 (0.5%)	3 (1.4%)	2 (0.9%)
Seroma	11 (4.8%)	6 (2.6%)	0 (0%)	0 (0%)	5 (2.3%)
Fat necrosis	3 (1.3%)	1 (0.4%)	0 (0%)	0 (0%)	2 (0.9%)

V_{200} ($p = 0.0208$) and skin telangiectasia, V_{90}, V_{150} and seroma formation ($p = 0.0217$ and 0.0255, respectively), V_{90} and fat necrosis ($p = 0.0368$), and skin spacing and skin dose with any late toxicity ($p = 0.0032$ and 0.0101, respectively).

Recurrence and survival

For all patients, the crude rate of TR/MM was 2.0% ($n = 5$) and the IBTR was 4% ($n = 10$) with one being a simultaneous breast and regional failure. Nine patients had an isolated ipsilateral breast only failure (3.6%). The contralateral and regional only recurrence rates were 2.0% ($n = 5$) and 0.80% ($n = 2$), respectively. There were two distant metastases (0.80%). The 4-year actuarial recurrence rates for TR/MM and IBTR were 2.3% and 3.6%, respectively. The 4-year actuarial rates for overall survival, cause-specific survival, and disease-free survival were 97%, 98%, and 92%, respectively. Table 5 provides raw rates and 4-year actuarial rates for all categories of recurrence. Of the 10 recurrences, seven underwent mastectomy.

Comesis

Of the entire population, 85.9% had excellent/good cosmesis at 60 months. Ten of the 11 reporting sites had excellent/good cosmesis in 96.2%, and in one center, excellent/good cosmesis was reported in 57.9%.

Table 5
Recurrence rates

Number of breasts (all breasts)	$N = 250$, raw rate, *N* (%)	4-Year actuarial rate, %
Breast only failure (IBTR)[a]	9 (3.6)	3.6
TR/MM failure[a]	5 (2.0)	2.3
Regional only failure[a]	2 (0.8)	1.0
Distant failure	2 (0.8)	0.9
Contralateral failure	5 (2.0)	1.9
Overall survival	242 (96.8)	97.2
Cause-specific survival	246 (98.4)	98.5
Disease-free survival	229 (91.6)	91.8

TR/MM = true recurrence/marginal miss; IBTR = ipsilateral breast tumor recurrence.

[a] Local failures occurring without or before distant metastases.

Discussion

Phase III trials with 5- and 10-year followup and excellent outcomes support the use of brachytherapy-based APBI, including the study conducted by GEC-ESTRO proving the equivalence of APBI with brachytherapy to WBI in local control, disease-free survival, and overall survival (1–3). In addition, both a single institutional series with 10-year followup and a multi-institutional registry with 6.9 year followup (PROMIS trial) have been reported for balloon or interstitial APBI (8, 9). Five-year outcome on the use of the MammoSite device on a patient registry has been reported by the American Society of Breast Surgeons (ASBrS) as well (26). As the multichannel devices are newer, there is less data; however, 3-year data from a multichannel single-entry device has also been reported (19). In the trial reported here, the 4-year actuarial IBTR was 3.6% and that compares favorably to the actuarial 5-year IBTR in the Hungarian trial at 4.7%, the 10-year matched-pair analysis at 4.2%, the PROMIS rate of 7.6%, 3.8% in the ASBrS report, and 3-year crude IBTR from the multilumen single-entry device of 2.2% (2, 8, 9, 19, 20).

Other methods of APBI include three-dimensional external beam and proton therapies. The Radiation Therapy Oncology Group (RTOG) 3D conformal study 0319 published a 4-year IBTR of 6% (27). Proton therapy for APBI was reported from a prospective Phase I trial and demonstrated a local recurrence rate of 11% at 7 years (14). More detailed comparative recurrence rates can be found in Table 6.

There have been several published dosimetric reports on APBI with protons (28, 29, 30). One clinical report was written by Galland-Girodet *et al.* and compared protons (32 Gy/CGE in eight twice-daily fractions) to 3D conformal therapy in a Phase I trial, and local failures were 11% for the proton group and 4% for the photon group ($p = 0.22$) in the two arms with 7 years of followup. The proton beam therapy led to poorer cosmesis with increased telangiectasias (69%) and color change although patient satisfaction in the cohort was 93% (22). The largest series is from Loma Linda with a median followup of 60 months treating with 40 CGE in 10 daily fractions. In this series, good-to-excellent cosmesis was reported >90% and the telangiectasia rate was much

Table 6
Comparison—SCRG, Polgar, and ASBrS registry at 5-yr median followup

Variable	This report	GEC-ESTRO	Polgar 10 yr	Polgar 5 yr	Beaumont 10 yr	PROMIS	Proton phase 1	ASBS-Shah 5-yr	Contura 3 yr
N (breasts)	250	633	128[a]	128[a]	274	1356	19	1449	342
Median F/U (mo)	59.5	79	122	66	94	83	82.5	63	36
Invasive (%)/DCIS (%)	73/27	94/6	100/0	100/0	82/18	73/18	89/0	87/13	77/21
IBTR (%)	3.6	1.4	5.5	4.7	4.2[b]	5.2	11.0	2.8	2.9
TR/MM (%)	2.0[c]	0.5	2.4	2.3	1.4[b]	1.7	—	0.8	2.3
Elsewhere (%)	2.0	0.5	3.1	2.3	2.8[b]	2.4	—	2.0	0.6
Axillary (%)	0.8	0.5	1.5	0.8[d]	—	—	—	0.6	1.2
Distant (%)	0.8	0.8	5.5	3.9	6[b]	2.5	—	1.8	—
Contralateral (%)	2.0	0.8	7.0	6.2	3[b]	2.8	—	1.5	0.9
IBTR actuarial rate (%)	3.6 (4-yr rate)		5.9 (10-yr rate)	4.7 (5-yr rate)	4.2 (10-yr rate)	7.6 (10-yr rate)	—	3.8 (5-yr rate)	3.8 (5-yr rate)

TR/MM = true recurrence/marginal miss; IBTR = ipsilateral breast tumor recurrence; DCIS = ductal carcinoma in situ; ASBS = American Society of Breast Surgeons; PROMIS = pooled registry of multicatheter interstitial sites; HDR = high dose rate.

[a] Of 128 partial breast subjects, 88 were HDR multicatheter (7 × 5.2 Gy b.i.d.), 40 received limited field electron beam.

[b] Ten-year rates.

[c] 1 TR/MM failure diagnosed simultaneously with regional failure.

[d] Does not include another 0.8% for supraclavicular failure.

lower at 7%, with 62% experiencing dermatitis. The recurrence rate at 5 years was 3% (31). A study from Korea published on 30 patients treated with 30 CGE in five daily fractions (32). Mild-to-moderate acute effects were seen in all but one treated patient. The cosmesis at 36 months was reported as good excellent in 69%. No recurrences had developed with a median followup of 59 months.

Regarding toxicity this report presents rates of Grade 2 or greater toxicity that are equivalent to other published PBI studies. The outliers are the ASBrS MammoSite study that reported a 13% symptomatic seroma rate and a 13% telangiectasia rate, but these toxicities were a driver for the innovation of new devices (see Table 4) (26). The recently published single-entry multilumen balloon trial demonstrated similar toxicities to the present series although the Grade 2 telangiectasia rate may be a bit higher with the strut device (3% vs. 0%), but this may be related to the treatment of women with smaller skin bridges. The percent of patients in this report with ≤5 mm and ≤3 mm skin bridges were 29% and 17% but not reported in other series so direct comparison is not possible.

When compared to the data from external beam with photons and protons, the brachytherapy literature suggests less toxicity. Updates from the RTOG 0319 series demonstrate at a median followup of 5 years, a higher toxicity rate than any published brachytherapy series with ≥ Grade 2 rates of hyperpigmentation, fibrosis, and telangiectasia of 15.4%, 17.3% and 15.4%, respectively, with a deterioration in cosmesis (33). The RAPID trial published lower Grade 2 rates of telangiectasia and induration than the RTOG trial with rates of 4% and 8%, respectively, at 5 years (34). These are more comparable to the brachytherapy rates. The proton series graded toxicities somewhat differently but reported moderate skin changes in 44% and telangiectasias >4 cm^2 in 38.5% (22).

Although our cosmesis scores are similar to other published series, we also found that cosmesis reports vary among centers. One center was an outlier with excellent-to-good cosmesis in 57.9% vs. 96.2% in the other 10 centers. This was noted in another report, and the explanation seemed to reflect the difference between low- and high-volume centers (19). That data were not collected in this series so a definitive explanation cannot be elucidated other than representing either poorer cosmesis at this one center or differences in subjective grading compared to other centers. Of note, the RAPID trial published significantly higher fair/poor cosmesis with external beam APBI (29%) compared to WBI (17%) (34).

In this series, dosimetric targets were met in virtually all patients and are similar to other published series with excellent target coverage and normal tissue avoidance. With the struts adjacent to the target tissue, the allowable target for V_{200} is more similar to the interstitial target than the balloon target. But, as demonstrated in this series, this has not led to

increased toxicity. A recent single institutional series compared a large cohort of patients ($n = 594$) with APBI using different single-entry devices. This report also observed outstanding target coverage with excellent skin and rib sparing (35).

On univariate analysis, there were associations between dose and telangiectasia. This would be an expected finding as dose and skin spacing are related, and other publications have demonstrated a similar correlation. V_{90} and V_{150} correlate with symptomatic seroma, and V_{90} correlates with fat necrosis, but the numbers were too small to allow for alteration of guidelines and were overall low and comparable to other series. The Surveillance, Epidemiology, and End Results Medicare claims database by Smith *et al.* (17) suggested that increased recurrence or toxicity led to an increased mastectomy rate from 2.2% to 3.9%. Smith *et al.* reported at 5 years a 15% rate of breast pain, a 16% infection rate, an 8.3% rate of fat necrosis, and a 4.5% rate of rib fracture, but grades of toxicities were not reported to allow a more granular comparison. In this report, an actuarial recurrence rate at 4 years of 3.6% and a Grade 3 or greater toxicity of 0.9% breast pain, 1.7% seroma, and 0.4% fat necrosis highlights that this nationwide database may overestimate the need for mastectomy, especially when viewed in the context that the time period covered was with older devices and techniques. In this series, the infection rate was low at 3.7% and the mastectomy rate, secondary to ipsilateral breast recurrence, was 2.8%.

The strengths of this report include its multi-institutional participation and robust numbers ($n = 250$) with the longest followup for a single-entry multilumen breast brachytherapy device. Selection criteria were simply the first 250 subjects accrued, and it is felt this reduces the potential for selection bias as it reports on all comers rather than applying any screens to the patient selection process. It is limited by its retrospective nature, which may confound data as institutional toxicity reporting and treatment policies may differ.

Conclusions

The multilumen applicators were designed to simplify brachytherapy APBI compared to interstitial brachytherapy, allowing the advantages of brachytherapy over other forms of accelerated partial breast radiation therapy accessible to more women. The strut open architecture design and multiple catheter options allow dose sculpting to each patient's unique anatomy and cavity location. This flexibility helps to overcome prior concerns with skin spacing and tumor beds positioned between the overlying skin and chestwall that limited patient eligibility. This report presents the median 59.5 month outcomes for patients treated with the strut-based applicator and confirms excellent tumor control comparable to other published APBI rates and survival with low toxicity. Compared to external beam techniques for APBI, brachytherapy seems to be as effective, with less toxicity.

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