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Scientific Article

Radiation-Induced Brachial Plexopathy in Patients With Breast Cancer Treated With Comprehensive Adjuvant Radiation Therapy

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Abstract

Purpose: Our purpose was to describe the risk of radiation-induced brachial plexopathy (RIBP) in patients with breast cancer who received comprehensive adjuvant radiation therapy (RT).

Methods and Materials: Records for 498 patients who received comprehensive adjuvant RT (treatment of any residual breast tissue, the underlying chest wall, and regional nodes) between 2004 and 2012 were retrospectively reviewed. All patients were treated with conventional 3 to 5 field technique (CRT) until 2008, after which intensity modulated RT (IMRT) was introduced. RIBP events were determined by reviewing follow-up documentation from oncologic care providers. Patients with RIBP were matched (1:2) with a control group of patients who received CRT and a group of patients who received IMRT. Dosimetric analyses were performed in these patients to determine whether there were differences in ipsilateral brachial plexus dose distribution between RIBP and control groups.

Results: Median study follow-up was 88 months for the overall cohort and 92 months for the IMRT cohort. RIBP occurred in 4 CRT patients (1.6%) and 1 IMRT patient (0.4%) ($P = .20$). All patients with RIBP in the CRT cohort received a posterior axillary boost. Maximum dose to the brachial plexus in RIBP, CRT control, and IMRT control patients had median values of 56.0 Gy (range, 49.7-65.1), 54.8 Gy (47.4-60.5), and 54.8 Gy (54.2-57.3), respectively.

Conclusions: RIBP remains a rare complication of comprehensive adjuvant breast radiation and no clear dosimetric predictors for RIBP were identified in this study. The IMRT technique does not appear to adversely affect the development of this late toxicity.

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Research data are stored in an institutional repository and will be shared upon request to the corresponding author.

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Introduction

Patients with locally advanced breast cancer often require treatment with a combination of surgery, chemotherapy, and comprehensive adjuvant radiation therapy (RT), which we operationally define as treatment to any residual breast tissue, the chest wall, and the regional lymph nodes. Historically, comprehensive adjuvant RT at our institution was delivered using opposed tangent fields along with a matched supraclavicular field. Internal mammary lymph nodes (IMLNs) were routinely treated via partially deep tangents or a separate IMLN field.[1] Additionally, a posterior axillary boost (PAB) field was often used. With the use of computed tomography-based simulation, newer techniques such as inverse planning intensity modulated radiation therapy (IMRT) have emerged to aid in delivering comprehensive adjuvant radiation treatments.[2]

With improving local and systemic treatments, a significant proportion of patients receiving comprehensive RT achieve long-term survival.[3] As a result, toxicity from RT is of substantial concern in this population. Chronic, rare toxicities such as radiation-induced brachial plexopathy (RIBP) have previously been associated with conventional RT to the breast and regional lymph nodes.[4-6] Therapy-related complications involving the upper extremity negatively affect patient quality of life.[7] However, studies evaluating long-term toxicities in patients receiving comprehensive RT with modern techniques are lacking. We identified patients with breast cancer treated at our institution with conventional RT (CRT) or IMRT techniques for comprehensive adjuvant RT and reported RIBP outcomes to improve patient counseling regarding risks of treatment.

Methods and Materials

Patient selection

We reviewed the medical records of patients with breast cancer treated at our institution with comprehensive adjuvant RT between 2004 and 2012. All patients were adults older than 18 years of age. The study was approved by the institutional review board.

Radiation therapy

Comprehensive adjuvant RT was defined as treatment to any residual breast tissue, the underlying chest wall, IMLN, axillary lymph nodes, and supraclavicular lymph nodes (SCVs). CRT was exclusively used to deliver radiation between 2004 and 2007. In 2008, IMRT became an option for delivering comprehensive treatments, with over 50% of patients receiving IMRT that year. By 2011, more than 90% of patients were treated with IMRT, and the current standard of practice at our institution is to use IMRT for all patients receiving comprehensive adjuvant RT.

For the CRT technique, patients were simulated in the supine position with both arms above their heads using a slant board. Radiation to the residual breast tissue and chest wall was delivered with opposed tangential fields. The table and collimator were optimized to eliminate divergence superiorly. The SCV fields were directed in an anterior-posterior direction with a slight oblique angle to avoid beam exit through the spinal cord and central neck structures. This field was matched via a half-beam block to the superior border of the tangential fields. IMLNs were routinely treated to the first 3 intercostal spaces using partially deep tangents or a separate IMLN field. Some patients also received an additional dose with a PAB field for risk factors such as nodal extracapsular extension or when dose to the axillary midplane was below 50 Gy. Weekly MV imaging was performed for treatment set-up verification.

For IMRT, patients were simulated in the supine position with both arms up above their heads using either an alpha cradle or slant board. The clinical residual breast tissue, chest wall, and regional nodes were contoured as a single volume. Medial and lateral SCVs, interpectoral nodes, axillary nodes, and IMLNs from the first 3 intercostal spaces were included in the treatment volume for all IMRT patients. These target volumes are similar to those described by DeSelm and colleagues.[8] If IMLN involvement was noted on imaging, then all IMLN spaces were included in the treatment volume. Generally, patients were treated with 10 or more beam angles spaced approximately 20 to 30° apart. Daily cone beam computed tomography (CBCT) was used for treatment set-up.

RT courses were delivered using photons with the option of using electrons for boost treatments or for at least two-thirds of the IMLN fields for CRT patients. For all patients, median delivered dose and fractionation for breast and chest-wall was 50.4 Gy (range, 37.8–55.8) in 1.8 to 2 Gy/fraction, and median delivered dose and fractionation for SCV nodal region was 50.4 Gy (range, 37.8–58.0) in 1.8 to 2 Gy/fraction. Only 4 patients (2 patients each in the CRT and IMRT cohorts) received prescription doses higher than 50.4 Gy to the breast or chest wall volume. Higher doses were used in some treatment courses before 2010 to address risk factors such as lymphovascular space invasion and grade 3 disease as per physician discretion. One patient declined to complete the entire course of RT and received 37.8 Gy out of the planned 50.4 Gy.

Study endpoints and statistical analysis

Brachial plexopathy was defined as chronic symptoms of paresthesia, numbness, and/or weakness in the ipsilateral arm beginning after completion of RT. Imaging and electromyography (EMG) studies were reviewed, if available. Patients who developed brachial plexopathy secondary to tumor recurrence based on imaging or demonstrated symptoms before completion of RT were not classified as patients with RIBP. Time to RIBP was calculated from completion date of RT course. All patients underwent follow-up evaluation with a radiation oncologist, medical oncologist, breast surgeon, physical medicine and rehabilitation physicians, or other providers.

Matched control cohorts of patients without RIBP were identified using exact matching in a 1:2 fashion using patient characteristics of age at completion of RT (within 10 years), receiving axillary lymph node dissection (ALND) or not, breast conserving surgery or mastectomy, and dose to SCVs (within 10 Gy). Chemotherapy was not used as a matching criterion, as the ultimate purpose of matching was to identify patients for the dosimetric analysis of brachial plexus dose distribution.

Separate control cohorts were created for patients receiving CRT and IMRT. RT plans for patients with RIBP and matched control patients were retrieved for dosimetric analysis. The ipsilateral brachial plexus was not routinely contoured during RT planning at our institution and thus, this structure was retrospectively contoured by a single radiation oncologist on the unarchived treatment plans according to the Radiation Therapy Oncology Group guidelines.[9] Dosimetric data extracted from plans included mean dose (D_{mean}), maximum dose (D_{max}), V40 Gy (volume of brachial plexus receiving 40 Gy or higher), V45 Gy, V50 Gy, and V55 Gy for the ipsilateral brachial plexus.

Statistical analysis was performed using Statistical Package for the Social Sciences version 23 (IBM Corp., Armonk, NY). Baseline patient characteristics were compared using Mann-Whitney U-test and χ^2 test (Fisher exact test for small cell counts) for continuous and categorical variables, respectively.

Results

A total of 498 patients met criteria for inclusion in our study, with 501 breast cancers treated with comprehensive adjuvant RT. Our cohort included 3 patients who received bilateral comprehensive adjuvant RT. The CRT technique was used to treat 243 cases and the IMRT technique was used to treat 258 cases. Median follow-up was 88 months in the overall cohort (80 months in the CRT group vs 92 months in the IMRT group). Rates of breast conserving therapy decreased from 45% in 2004 to 24% in 2012. Seven patients did not receive any primary breast surgery and received definitive chemotherapy and RT (4 patients had occult primaries for which surgery was not performed, 2 patients declined surgery, and 1 patient was medically inoperable). Three patients were staged as clinical T0 but had pathologic findings in the surgically removed breast and nodal tissue that required comprehensive adjuvant RT. Rates of ALND did not differ significantly between the groups and remained similar throughout the study period from 2004 (84%) to 2012 (80%). Complete baseline characteristics are provided in Table 1.

Clinical signs and symptoms of brachial plexopathy were noted in 7 patients. Tumor involvement of the ipsilateral brachial plexus was identified in 1 patient and another patient developed brachial plexopathy before completion of RT presumably secondary to axillary dissection. As a result, 5 patients were determined to have RIBP. None of the 4 patients who received a prescription dose greater than 50.4 Gy to the breast or chest wall developed RIBP during follow-up. All patients with RIBP presented with weakness in the ipsilateral arm while 3 patients also presented with paresthesia. The location of the plexopathy was corroborated with EMG studies and found in the C5 to 6 trunk for 1 patient and C8–T1 trunk for 2 patients. The other 2 patients with RIBP did not receive an EMG evaluation. All patients with RIBP received physical therapy and patients were also prescribed gabapentin to manage symptoms. Median time to development of RIBP was 45 months (range, 19-127 months). Four patients who received CRT (1.6%) and 1 patient who received IMRT (0.4%) developed RIBP (Fisher exact $P = .20$) at time of analysis. The matched control groups consisted of 10 CRT patients and 10 IMRT patients. Patient and treatment characteristics for RIBP and matched control patients are listed in Table 2. Treatment plans were available and analyzed in all patients with RIBP, and all matched control patients with dosimetric characteristics are reported in Table 3. The median D_{mean} and D_{max} to the brachial plexus of patients with RIBP were 46.7 Gy and 56.0 Gy, respectively. Median brachial plexus D_{mean} and D_{max} in the CRT matched cohort were 40.0 Gy and 54.8 Gy, respectively. Median D_{mean} and D_{max} in the IMRT matched cohort were 44.1 Gy and 54.8 Gy, respectively.

Discussion

Development of upper extremity toxicities such as lymphedema and brachial plexopathy from breast cancer therapy can have deleterious effects on patient quality of life.[7] As modern techniques of RT delivery such as IMRT are introduced to the clinic, it is important to identify their

Table 1 Baseline patient, tumor, and treatment characteristics

Characteristic	Overall (n = 501)	CRT (n = 243)	IMRT (n = 258)	*P* value
Median age (in years) at completion of RT [range]	53 [25-89]	53 [25-89]	52 [27-86]	.67
ER+* (%)	[n = 499] 334 (67)	[n = 241] 157 (65)	[n = 258] 177 (69)	.41
HER2+*	[n = 499] 116 (23)	[n = 241] 54 (22)	[n = 258] 62 (24)	.67
Primary breast surgery				
BCT	178 (36)	97 (40)	81 (31)	.09
Mastectomy	316 (63)	144 (59)	172 (67)	
Not performed	7 (1)	2 (1)	5 (2)	
ALND performed	424 (85)	212 (87)	212 (82)	.12
Number of LNs examined*	[n = 496] 12 [0-38]	[n = 239] 12 [0-38]	[n = 257] 11 [0-38]	.56
Chemotherapy	466 (93)	226 (93)	240 (92)	.99
Hormone therapy received	344 (69)	162 (67)	182 (71)	.35
Posterior axillary boost	130 (26)	130 (53)	0	N/A

Abbreviations: ALND = axillary lymph node dissection; BCT = breast conserving therapy; CRT = conventional RT; ER+ = estrogen receptor positive; HER2+ = Her-2-neu receptor positive; IMRT = intensity modulated RT; LNs = lymph nodes; RT = radiation therapy.

* Data missing for some patients (ER and HER2 status were missing for 2 patients in the CRT cohort. Data on number of LNs examined were missing for 4 patients in the CRT cohort and 1 patient in the IMRT cohort).

effect on normal tissue toxicity outcomes. To our knowledge, this is the first study to evaluate the risk of RIBP in patients receiving comprehensive adjuvant RT with IMRT.

When our study cohort was stratified by RT technique, there was no significant difference in rate of RIBP development between patients receiving CRT or IMRT. Another modern case series reported a RIBP rate of 0.48% in a cohort of 629 patients with breast cancer receiving chest wall and ipsilateral SCV radiation with the CRT technique where the average D_{mean} and D_{max} to the brachial plexus in patients with RIPB were 47 Gy and 59 Gy, respectively.[5] Historical data on the development of brachial plexopathy in a large cohort of patients with early stage breast cancer by Pierce et al[10] reported a RIBP rate of 1.8% in patients receiving SCV radiation, 1.3% in patients with axillary dose of 50 Gy, 5.6% in patients with axillary dose > 50 Gy, and increased risk of RIBP with use of chemotherapy. In our study, all patients with RIBP in the CRT group received PAB, and 4 out of 5 patients with RIBP received adjuvant chemotherapy. The combination of surgery and RT to the axilla may also increase the risk of brachial plexopathy as 4 out of 5 patients with RIBP received ALND. In support of this argument, Lundstedt et al[11] reported brachial plexopathy symptoms of paresthesia and weakness in 6.3% of patients treated with ALND and regional nodal RT, 3.8% of patients with ALND alone, and 2.7% of patients with no axillary therapy. The CRT and IMRT cohorts in this study had similar rates of chemotherapy use and ALND, indicating that both groups had comparable baseline risk for developing RIBP.[12] One patient with RIPB in our study did not receive ALND or adjuvant chemotherapy and had the lowest D_{mean} and D_{max} of all patients with RIPB, suggesting that other patient-intrinsic factors may affect susceptibility. These findings suggest a multifactorial etiology for brachial plexopathy after oncologic treatments in patients with breast cancer. Of note, median time to RIBP in the literature ranges from 1 to 4 years after RT, which is within the median follow-up obtained for this study.[6] These data show that RIBP remains a rare event after comprehensive adjuvant RT, and RIBP incidence does not appear to be increased with use of IMRT.

Standard RT prescription doses for comprehensive adjuvant treatments fall within brachial plexus dose limits recommended in the literature.[13] With use of boost fields and patient anatomic variance, brachial plexus dose distribution may exceed those limits in certain cases, which hypothetically could result in RIBP. To investigate this possibility, we performed dosimetric analysis of treatment plans of patients with RIPB and matched control patients. D_{mean}, D_{max}, and dose distribution for the contoured brachial plexus structures did not demonstrate clinically meaningful differences between patients with RIPB and matched control patients. Control IMRT patients had similar D_{mean} and D_{max} values compared with CRT patients although V50 Gy was relatively higher. A similar dosimetric analysis by Wu et al[5] also did not identify any relationship between brachial plexus D_{max} and RIBP; all patients in their study were treated with CRT. Lundstedt et al[14] identified a dose-volume relationship for the brachial plexus (V40 Gy > 13.5 cm^3) that resulted in significant increase in patient-reported paresthesia, although they cautioned against the use of this association

Table 2 RIBP and matched control baseline characteristics

RIBP patients

Patient	Age	BCT	ALND	Chemotherapy	RT technique	Breast RT dose	SCV RT dose	IM field	PAB field	SCV field energy (MV)	SCV field depth (cm)
A	64	No	No	None	CRT	45	40.5	Yes	Yes	6	3.37
B	62	No	Yes	Adjuvant AC-TH	CRT	50.4	50.4	No	Yes	6	4.50
C	54	No	Yes	Adjuvant AC-TH	CRT	50.4	50.4	No	Yes	10	5.06
D	33	No	Yes	Adjuvant AC-T	CRT	50.4	50.4	No	Yes	6	3
E	62	No	Yes	Adjuvant AC-T	IMRT	50.4	50.4	N/A	N/A	N/A	N/A

Matched 3D-CRT control patients

Patient	Age	BCT	ALND	Chemotherapy	RT technique	Breast RT dose	SCV RT dose	IM field	PAB field	SCV field energy (MV)	SCV field depth (cm)
A1	61	No	No	Neoadjuvant AC-TH	CRT	50.4	50.4	Yes	No	10	3.96
A2	62	No	No	Neoadjuvant AC-TH	CRT	50.4	50.4	No	No	6	5.82
B1	57	No	Yes	Neoadjuvant and adjuvant HT	CRT	50.4	50.4	No	No	6	3.2
B2	54	No	Yes	Adjuvant AC-T	CRT	50	46	Yes	Yes	6	3.09
C1	50	No	Yes	Neoadjuvant herceptin, vinorelbine, and doxorubicin	CRT	50.4	50.4	No	Yes	6	3
C2	45	No	Yes	Adjuvant AC-T	CRT	50.4	50.4	Yes	Yes	6	2.9
D1	30	No	Yes	Neoadjuvant and adjuvant HT	CRT	54	54	No	Yes	6	3.0
D2*	31	No	Yes	Neoadjuvant FEC-T	CRT	50	46	Yes	No	10	—
E1	58	No	Yes	Adjuvant AC-T	CRT	50.4	50.4	No	Yes	10	3.7
E2	68	No	Yes	Neoadjuvant FEC-T	CRT	50	46	Yes	Yes	6	4.7

Matched IMRT control patients

Patient	Age	BCT	ALND	Chemotherapy	RT technique	Breast RT dose	SCV RT dose	IM field	PAB field	SCV field energy (MV)	SCV field depth (cm)
AA1	64	No	No	Adjuvant FEC-T	IMRT	50.4	50.4	N/A	N/A	N/A	N/A
AA2	67	No	No	Adjuvant FEC-T	IMRT	50.4	50.4	N/A	N/A	N/A	N/A
BB1	64	No	Yes	Neoadjuvant AC-T	IMRT	50.4	50.4	N/A	N/A	N/A	N/A
BB2	67	No	Yes	Adjuvant TCH	IMRT	50.4	50.4	N/A	N/A	N/A	N/A
CC1	56	No	Yes	Neoadjuvant FEC-TH	IMRT	50.4	50.4	N/A	N/A	N/A	N/A
CC2	49	No	Yes	Adjuvant FEC-T	IMRT	50.4	50.4	N/A	N/A	N/A	N/A
DD1	42	No	Yes	Adjuvant FEC-TH	IMRT	50.4	50.4	N/A	N/A	N/A	N/A
DD2	42	No	Yes	Neoadjuvant FEC-T	IMRT	50.4	50.4	N/A	N/A	N/A	N/A
EE1	53	No	Yes	Neoadjuvant taxotere, cytoxan	IMRT	50.4	50.4	N/A	N/A	N/A	N/A
EE2	62	No	Yes	Adjuvant AC-T	IMRT	50.4	50.4	N/A	N/A	N/A	N/A

Abbreviations: 3D-CRT = 3-dimensional conventional RT; AC-T(H) = adriamycin, cytoxan, taxol, (herceptin); ALND = axillary lymph node dissection; BCT = breast conserving therapy; CRT = conventional RT; FEC-T(H) = fluorouracil, epirubicin, cytoxan, taxotere, (herceptin); HT = hormone therapy; IM = internal mammary; IMRT = intensity modulated RT; PAB = posterior axillary boost; RIBP = radiation-induced brachial plexopathy; RT = radiation therapy; SCV = supraclavicular nodal region.

Two control patients were matched to each radiation-induced brachial plexopathy (RIBP) patient. Control patients A1 and A2 are matched to RIBP patient A and so on for the remainder of the table.

* Data missing for patient D2.

due to lack of symptom confirmation with EMG studies. Modern image guided RT likely had a role in minimizing RIBP. Topolnjak and colleagues[15] demonstrated the value of CBCT in reducing daily setup errors in the treatment of patients with breast cancer with RT. We postulate that the use of daily CBCT during IMRT may have contributed to better set-up and dose delivery, and therefore mitigated the risk of RIBP.

Development of RIBP portends a lifelong complication, as the symptoms rarely completely resolve and the risk of developing this toxicity does not decrease with time.[16] Work-up for RIBP should include imaging to rule out tumor involvement of the brachial plexus. In particular, magnetic resonance imaging can help rule out tumor involvement as etiology of symptoms and may also help localize the plexopathy lesion.[17] Magnetic resonance

Table 3 RIBP and matched control dosimetric analysis

RIBP patients						
Patient	D_{mean} (Gy)	D_{max} (Gy)	V40 (%)	V45 (%)	V50 (%)	V55 (%)
A	40.8	49.7	63.2	46.0	0	0
B	46.7	54.0	93.5	73.9	27.1	0
C	47.1	56.0	90.5	85	46.2	0.6
D	49.4	65.1	81.5	79.7	76.1	54.4
E	40.3	57.2	69.9	65.2	52.5	4.3
Median values	46.7	56.0	81.5	73.9	46.2	0.6
Matched 3D-CRT control patients						
Patient	D_{mean} (Gy)	D_{max} (Gy)	V40 (%)	V45 (%)	V50 (%)	V55 (%)
A1	39.3	54.3	70.7	61.1	22	0
A2	43.8	60.0	80.5	75.7	55.2	3.3
B1	38.7	54.3	73.6	71.4	30.2	0
B2	39.6	53.2	76.9	57.3	3.4	0
C1	44.3	54.9	80.8	78.1	65.2	0
C2	44.3	57.8	77.4	75.1	69.0	17.3
D1	40.4	60.5	68.2	66.5	61.6	44.4
D2	33.3	47.4	54.7	1.4	0	0
E1	44.7	54.7	83.1	77.5	47.8	0
E2	35.3	57.9	62.4	58.7	40.2	15.7
Median values	40.0	54.8	75.3	69.0	44	0
Matched IMRT control patients						
Patient	D_{mean} (Gy)	D_{max} (Gy)	V40 (%)	V45 (%)	V50 (%)	V55 (%)
AA1	40.2	55.4	70.3	65.6	47.5	0.2
AA2	49.7	57.3	93.3	92.1	73.6	3.5
BB1	43.3	54.3	76.9	73.4	68.6	0
BB2	41.5	56.0	74.0	68.7	61.2	2.1
CC1	48.8	54.6	88.8	85.6	74.0	0
CC2	44.9	54.2	75.6	71.1	66.0	0
DD1	45.6	54.9	80.3	72.9	64.3	0
DD2	49.0	54.3	93.3	89.5	59.1	0
EE1	38.9	52.6	60.3	56.1	43.3	0
EE2	37.8	55.8	65.5	60.8	44.6	0.6
Median values	44.1	54.8	76.3	72	63	0

Abbreviations: 3D-CRT = 3-dimensional conventional radiation therapy; IMRT = intensity modulated RT; RIBP = radiation-induced brachial plexopathy; RT = radiation therapy.

imaging in our patients who developed RIBP showed no tumor in the region of the brachial plexus but did not always clearly identify the anatomic location of the plexopathy lesion. On the other hand, EMG can be used to identify the affected region of the brachial plexus. Although no clear dosimetric properties are known to predict RIBP, clinical factors such as aggressive axillary surgery and RT are known to increase the risk of this toxicity. Current treatment options for RIBP provide symptom management but no definite cure.[6] Medical management with gabapentin, pregabalin, opioid, and nonopioid analgesics is often used in conjunction with physical therapy (as was recommended to all our patients with RIPB) to improve neuropathic symptoms and weakness, respectively.

There are fundamental limitations to the conclusions that can be drawn from this analysis. Retrospective study design inherently leads to the possibility of patient selection bias and incomplete collection of toxicity data. However, the outcome of interest in this study is a chronic and progressive toxicity that is likely to be noted by care providers or patients during follow-up visits. Only 5 patients in our cohort developed RIBP, which limited statistical analyses. We also note that follow-up for the CRT cohort was shorter than the IMRT cohort even though the CRT cohort is chronologically older. There are a couple of key reasons for this difference in follow- up. First, this study spanned a lengthy period, from 2004 through 2015. During the early portions of the study period, multiple transitions occurred in providers taking care of patients with a diagnosis of breast cancer at our institution. As such, follow-up during this period suffered owing to lack of patients returning to the clinic given their primary radiation oncologist was no longer present. These transitions were not present in the latter half of the study period, which is when IMRT was used in our clinic. Another shortcoming of the earlier half of the study period was the lack of a unified electronic medical record system. Follow-ups for patients may have occurred at neighboring clinics and institutions, but these outside records were not easily available for review. With our modern electronic medical record, patients can easily provide consent for outside records to be brought into the system and this has extended the available follow-up period. Once again, this favored the follow-up length for the IMRT cohort. Even with these limitations, this study provided a thorough evaluation of the risk of RIBP in the setting of comprehensive adjuvant RT for breast cancer using modern treatment techniques.

Conclusions

In summary, RIBP is a rare but devastating consequence of comprehensive adjuvant RT. Our study did not identify any dosimetric predictors for RIBP given the rarity of this outcome, but the rate of RIBP in our cohort compared well with prior data from conventionally treated breast cancer cohorts. Common factors for RIBP included ALND and the use of PAB fields among patients receiving CRT. IMRT did not increase risk for development of RIBP. Studies evaluating IMRT technique in cohorts with prospectively collected toxicity data are needed to establish whether IMRT can reduce the incidence of RIBP for comprehensive adjuvant RT.

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