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Breast

Presence of Tissue Expanders Does Not Affect Radiotherapy Dose Distribution to Heart and Lungs

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Background: Breast cancer treatment often involves mastectomy and postmastectomy radiotherapy (PMRT). PMRT rates are increasing and can improve outcomes in node-positive cases. Although the risks of PMRT to reconstructed breasts are known, the influence of tissue expanders (TEs) on radiation to nearby organs such as the heart and lungs remains unclear.

Methods: Patients who underwent total mastectomy and completed a full course of PMRT with 3-dimensional computer tomography planning between January 2014 and August 2022 at Loyola University Medical Center were included. Patient dose statistics for ipsilateral lung, heart, and clinical target volume, as well as demographics, clinical characteristics, PRMT boost, and bolus were collected. Dose statistics for ipsilateral lung and heart were compared between mastectomy versus mastectomy + TE, and dose statistics were compared between dichotomized TE intraoperative fill volumes. Correlations between dose statistics and BMI were analyzed.

Results: A total of 124 patients were included in the study. There were no significant differences in lung or heart radiotherapy across all dose metrics between patients who underwent mastectomy versus mastectomy + TE, or between patients with TE fill volume 60 mL or less versus 60 mL or more. Correlations between BMI and heart maximum dose ($P = 0.03$) were significantly different and showed a positive, monoclonal correlation (correlation: 0.20, 95% confidence interval: 0.02–0.37).

Conclusions: The presence of TE and intraoperative expander fill volume did not affect dose distribution or complications to the organs at risk. Increased BMI correlated with an increased maximum dose to the heart. *(Plast Reconstr Surg Glob Open 2025;13:e6819; doi: 10.1097/GOX.0000000000006819; Published online 28 May 2025.)*

INTRODUCTION

Nearly 300,000 women a year are diagnosed with breast cancer in the United States.[1] The standard treatment for high-risk disease is mastectomy and radiation therapy. The rate of postmastectomy radiotherapy (PMRT) is on the rise, with 30.6% of T1-2N1 breast cancer patients receiving PMRT in 2004 and 47.1% in 2012.[2] PMRT can be performed before or after alloplastic breast reconstruction surgery with silicone implants or tissue expanders (TEs).[3,4] Although the risks of radiation such as capsular contraction and explanation from reconstructed breast radiation are well known, there are conflicting data on the risks of radiation to nearby structures such as the heart and lungs.

The goal of a PMRT plan is to deliver the recommended dose of radiation to the mastectomy cavity and chest wall (CW), known as the clinical target volume (CTV). The radiation beams are delivered at different tangents and weights to reach the recommended CTV dose while minimizing radiation to nearby anatomical structures. In PMRT, the heart and lungs are the main organs at risk (OARs) of collateral radiation.[5,6]

Data on the impact of PMRT on OARs in patients with TEs are limited and conflicting. Studies by Schechter et al[7] and Motwani et al[8] found that breast reconstruction

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significantly compromised treatment planning. Schechter et al[7] found that only 4 of the 18 plans resulted in optimal treatment of the entire CW while also avoiding the OARs. Motwani et al[8] similarly found that 52% of patients had compromised radiation plans compared with 7% of matched controls who did not have intervening reconstruction, with the greatest compromises seen in those with left-sided cancers.

A recent study by Liljegren et al[5] showed no difference in dose distribution in OARs with or without breast implants. However, this study did not include TEs with integrated magnetic ports in their evaluation and the patient population exhibited some key demographic differences when compared with the US population. Ohri et al[6] showed decreased lung V20 (the percentage of normal lung receiving at least 20 Gy), mean dose, and maximum dose compared with no implant reconstruction.

Various factors affect the distribution of radiation to the OARs. Implants may displace the soft tissue within the CTV and cause imprecise geometric matching of the tangential fields, affecting the radiation distribution.[9] In 3-dimensional computer tomography (3D CT) radiation, the OARs have been shown to be difficult to protect. Radiation may cause dose-dependent changes in the heart, such as conduction disorders, coronary artery disease, and cardiomyopathy. It can also cause dose-dependent radiation pneumonitis, one of the most common radiation therapy–induced adverse events.[5,8] Yet, few studies have investigated the effect of TEs on radiation dose to the OARs. To our knowledge, no studies investigate the effect of intraoperative expander fill on PMRT planning. Thus, we investigated the differences in PMRT doses to these OARs in patients with mastectomy only versus immediate reconstruction with a TE.

Takeaways

Question: Does the presence of tissue expanders (TEs) affect the distribution of radiation to organs at risk during postmastectomy radiotherapy (PMRT)?

Findings: TEs and varying fill volumes do not affect complication rates or radiation dose to the heart and lungs during PMRT. A higher body mass index is associated with increased heart radiation.

Meaning: Immediate reconstruction with TEs with varying intraoperative fill volumes is relatively safe to use during PMRT.

METHODS

Ethical Approval

Ethical approval was obtained from the institutional review board at Loyola University Chicago under approval number 215824 on August 29, 2022. The study was conducted in compliance with the ethical guidelines outlined by the institutional review board.

Study Population

We collected all women with breast cancer who underwent total mastectomy and completed ipsilateral PMRT with 3D CT between January 2014 and August 2022 at our institution. Patient body mass index (BMI), mastectomy date, side of mastectomy, resection weight, tumor size, lymph node (LN) involvement, chemotherapy type, and endocrine therapy use were obtained. TE placement and removal date, as well as intraoperative expander fill (mL) with saline, were collected for the mastectomy + TE cohort. Patients were identified in the ARIA oncology database, which is a software platform that presents radiation oncology treatments. It integrates patient-specific clinical data, such as body anthropometrics and treatment-specific data to support the planning and delivery of radiation therapy. EPIC Electronic Medical Record is integrated with ARIA, allowing streamlined patient management.

We collected dates of PMRT, total dose, number of fractions, LNs irradiated, CTV (CW only or CW plus LNs), and use of boost/bolus. Exclusion criteria included patients with implants other than TEs with magnetic ports, direct-to-silicone implant reconstructions, radiotherapy to only LNs, missing dosimetry data, or fractionation other than 50.4 Gy in 28 fractions.

Assessment of Dosage per Organ

Radiation dose distribution to the OARs was assessed using dose-volume histograms, which graphically represent the percentage of an organ's volume receiving a specific radiation dose. For example, V20Gy indicates the percentage of the lung volume that receives 20 Gy or more. VGy stands for "volume of Gray" and defines the volume of tissue that receives a specific dose of radiation. These histograms are generated by 3D CT-based treatment planning software (Eclipse, Varian Medical Systems, Palo Alto, CA), which calculates the dose delivered to each organ based on the patient's anatomy and beam parameters. Figure 1 provides a visual representation of dose distribution in ARIA.

Data Collection and Variables

Through the ARIA oncology database, we collected dose statistics for the ipsilateral lung, heart, and CTV. For the ipsilateral lung and heart, we captured organ volume (cm^3), minimum, maximum, and mean dose (Gy). We captured the percent of lung volume receiving a dose of 20 Gy or more (V20Gy, %) and the percent of heart volume receiving a dose of 25 Gy or more (V25Gy, %), which are standardized dosing measurements based on radiation modeling studies that accounted for radiation to the CW and LN while balancing clinically meaningful toxicities.[10,11]

We also assessed the coverage of the CTV, which is the area that needs to receive a certain radiation dose. We measured the percentage of CTV covered by at least 95% of the prescribed dose (CTV V95%). We evaluated CTV V95% in both absolute measures (volume in cubic centimeters covered by 95% of the prescribed dose) and

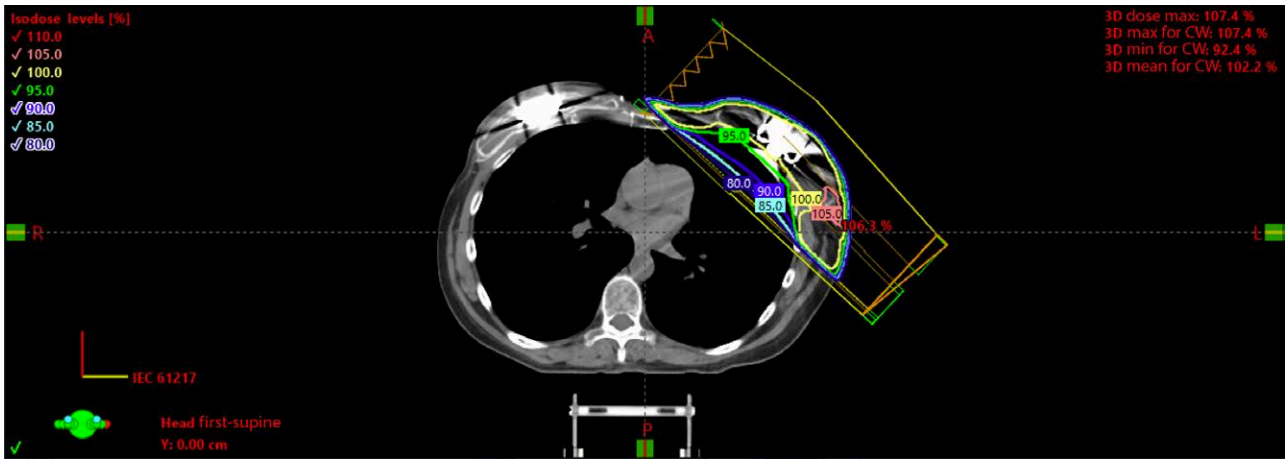

Fig. 1. Typical 3D CT and radiation plan on ARIA.

relative measures (percentage of CTV covered by 95% of the prescribed dose).

We accounted for both the size and shape of the rib cage by capturing internal transverse diameter, anteroposterior diameter, and hemithorax anteroposterior diameter taken at a specific slice of CT scans called the mammillary slice. We then calculated the chest wall index (CWi) as the ratio between the transverse and anteroposterior diameter. Relevant radiation oncology terms can be found in Table 1.

Statistical Analysis

SAS Version 9.4 was used for all statistical analysis. CW-only (n = 8) and CW + LN (n = 116) radiation plans were evaluated separately, although CW-only plans were not evaluated for statistical significance due to the small observed sample size. The Pearson chi-square or Fisher exact test assessed differences in patients with and without immediate breast reconstruction.

Univariable and multivariable binary logistic regression models estimate the effects of mastectomy procedure, mastectomy side, and CWi (CWi > 2.32 versus CWi < 2.32) on the logit of a lower lung V20Gy exposure (lung V20Gy < 30%) and lower heart mean dose exposure (heart mean dose < 5 Gy), separately. Odds ratios, along with corresponding Wald 95% confidence intervals and Wald chi-square *P* values, were reported. Lung, heart, and CTV radiotherapy dose metrics were summarized using medians and interquartile ranges, stratified by radiotherapy target and dichotomous intraoperative expander fill volume (<60 mL versus >60 mL). A 60 mL threshold was chosen as it represents the minimum standard expander fill at our institution. Wilcoxon rank sum tests compared dose metrics between fill volume groups among patients receiving radiotherapy to both the CW and LNs.

Spearman correlation coefficients described the bivariate correlations between lung, heart, and CTV dose metrics, BMI, and resection weight stratified by radiotherapy target. The Fisher *z* transformation was applied to each correlation coefficient, with 95% confidence intervals and *P* values reported.

RESULTS

Summary Statistics

This study included 124 unique patients undergoing PMRT. Sixty-six (53.23%) of these patients underwent a mastectomy only, whereas 58 (46.77%) underwent mastectomy and immediate TE placement before radiation. Significant differences in mastectomy side ($P < 0.01$), tumor size ($P = 0.04$), adjuvant chemotherapy ($P = 0.01$), bolus ($P < 0.01$), and age ($P < 0.01$) were observed between these 2 groups. Significantly more patients who underwent a bilateral mastectomy subsequently underwent reconstruction as well (65.52% versus 28.79%). Tumor size distribution was significantly different between the 2 mastectomy procedure groups. The bolus rate was significantly higher for patients who underwent mastectomy alone than for patients who underwent mastectomy plus reconstruction (93.94% versus 72.41%). Patients who underwent mastectomy alone were significantly older than patients who underwent mastectomy plus reconstruction (mean: 62.62 versus 48.19 y) (Table 2).

Complication Profile

The rates of common radiation-related complications were analyzed between the mastectomy-only and mastectomy + reconstruction groups, with no statistically significant differences observed. Radiation dermatitis occurred in 59 (89.4%) patients in the mastectomy-only group and in 53 (91.4%) patients in the mastectomy + reconstruction group ($P = 0.769$). Radiation pneumonitis was observed in 1 (1.5%) patient in the mastectomy-only group and in 2 (3.4%) patients in the mastectomy + reconstruction group, with no statistically significant difference ($P = 0.599$). Cardiology adverse events were also evaluated. Coronary artery disease was observed in 3 patients in both

Table 1. Relevant Radiation Oncology Terminology

Term	Simplified Explanation
ARIA oncology database	A software platform used in radiation oncology to manage patient treatment plans, dosimetry data, and clinical information, ensuring streamlined and accurate care
Dose-volume histogram	A graph that shows the relationship between the amount of radiation (dose) and the percentage of an organ receiving that dose. For example, it indicates what percentage of the lung receives at least 20 Gy (V20Gy)
Gray (Gy)	A unit of measurement for radiation dose, representing the amount of energy absorbed per kilogram of tissue
Volume of Gray (VGy)	The amount of tissue volume that absorbs a specific radiation dose (eg, V20Gy means 20 Gy absorbed by a percentage of lung tissue)
CTV	The specific area (eg, CW or LNs) that needs to receive radiation for effective treatment
OARs	Critical organs near the treatment area, such as the heart and lungs, that are vulnerable to unintended radiation exposure
Bolus	A material placed on the skin to increase radiation dose to superficial tissues, helping ensure adequate dose delivery
Boost	An extra dose of radiation aimed at a specific area, often used for treating residual cancer cells or high-risk regions
Transverse diameter	The width of the chest measured across the body in a horizontal plane, often used in treatment planning
Anteroposterior diameter	The depth of the chest measured from the front (sternum) to the back (spine), important for understanding CW geometry
CWi	A ratio of the transverse diameter to the anteroposterior diameter, used to describe chest shape and guide radiation planning
V20Gy (lung)	The percentage of lung tissue that receives at least 20 Gy of radiation. Higher values increase the risk of lung damage
V25Gy (heart)	The percentage of heart tissue that receives at least 25 Gy of radiation, with higher values increasing the risk of heart complications
Maximum dose	The highest radiation dose absorbed by any part of an organ. Helps assess the risk of tissue damage
Mean dose	The average radiation dose absorbed by the entire organ. Indicates overall exposure level
Fractionation	Dividing the total radiation dose into smaller doses delivered over multiple sessions to reduce side effects
3D CT planning	A method of using 3D CT scans to create detailed maps for precise radiation delivery to the target while sparing healthy tissue

groups before radiation. After radiation, coronary artery disease was seen in 3 patients in the mastectomy-only group and in 4 patients in the mastectomy + reconstruction group, with no statistically significant difference ($P = 0.705$). Pericarditis was not observed in any patient before radiation. However, after radiation, no cases of pericarditis were reported in the mastectomy-only group, whereas 1 case was observed in the mastectomy + reconstruction group. This difference was not statistically significant ($P = 0.468$). All other cardiology complications were not reported (Table 3).

Dosimetry of OARs

Univariate analysis revealed that immediate reconstruction after mastectomy did not affect lung or heart radiotherapy dose metrics (Table 4). Significant differences in CTV ($P < 0.01$), V95% ($P < 0.01$), V95% cm^3 ($P < 0.01$), V105% cm^3 ($P = 0.01$), transverse diameter ($P < 0.01$), anteroposterior diameter ($P < 0.01$), and ipsilateral internal diameter ($P < 0.01$) were observed between mastectomy procedure groups. All these metrics were significantly larger, higher, or longer for patients who underwent mastectomy plus reconstruction, when compared with patients who underwent mastectomy only (Table 5).

Regressions

The median CWi was 2.32. Mastectomy procedure ($P = 0.77$), mastectomy side ($P = 0.17$), and CWi ($P = 0.63$) all did not demonstrate a significant effect on lung or heart mean dose (Tables 6, 7). In addition, these variables did not demonstrate a significant effect on lung V20Gy among patients who had both their CWs and their LNs irradiated in adjusted analyses.

Mastectomy + TE Dosimetry

Among patients who underwent mastectomy plus reconstruction and had both their CWs and LNs targeted by radiotherapy, 21 (37.50%) had an intraoperative expander fill volume of 60 mL or less, and 35 (62.50%) had an intraoperative expander fill volume greater than 60 mL. We found that expander fill volume did not affect radiotherapy metrics among patients who underwent mastectomy plus reconstruction (Table 8).

Mastectomy Resection Weight Correlations

Correlations between resection weight and lung minimum dose ($P = 0.04$), and between resection weight and CTV ($P = 0.01$) were significantly different among patients who had both their CWs and LNs targeted by radiotherapy.

BMI Correlations

Correlations between BMI and lung maximum dose ($P = 0.02$), and between BMI and heart maximum dose ($P = 0.03$) were significantly different. The correlation between BMI and maximum heart dose showed a positive, monoclonal correlation (correlation: 0.20, 95% confidence interval: 0.02–0.37). The correlation between BMI and CTV ($P < 0.01$) was significantly different among patients who had both their CWs and LNs targeted by radiotherapy ($P < 0.01$).

DISCUSSION

Our study aimed to address the discrepancies in the literature about PMRT risks in patients with reconstructed breasts. Prior studies by Schechter et al[7] and Motwani et al[8] showed that reconstructed breasts compromise radiation treatment plans. Liljegren et al[5] found no difference in radiation to OARs in both reconstructed and nonreconstructed patients, but they did not include commonly used TEs with integrated magnetic ports. Our findings

Table 2. Comparison of Patient Demographics, Clinical Characteristics, and Radiotherapy Treatments Between Mastectomy Alone and Mastectomy + TE Implant for Immediate Breast Reconstruction Before PMRT

Variable	Mastectomy (n = 66), n (%)	Mastectomy + Reconstruction (n = 58), n (%)	Overall (n = 124), n (%)	*P*
Race				0.21
Asian	8 (12.12)	2 (3.45)	10 (8.06)	
Black	9 (13.64)	13 (22.41)	22 (17.74)	
Other	6 (9.09)	7 (12.07)	13 (10.48)	
White	43 (65.15)	36 (62.07)	79 (63.71)	
Ethnicity				0.29*
Missing	1 (1.52)	0 (0.00)	1 (0.81)	
Hispanic origin	6 (9.09)	9 (15.52)	15 (12.10)	
Non-Hispanic origin	59 (89.39)	49 (84.48)	108 (87.10)	
Mastectomy side				<0.01†
Bilateral	19 (28.79)	38 (65.52)	57 (45.97)	
Left	23 (34.85)	7 (12.07)	30 (24.19)	
Right	24 (36.36)	13 (22.41)	37 (29.84)	
Tumor size				0.04†
pT0	13 (19.70)	9 (15.52)	22 (17.74)	
pT1	16 (24.24)	21 (36.21)	37 (29.84)	
pT2	12 (18.18)	18 (31.03)	30 (24.19)	
pT3/pT4	25 (37.88)	10 (17.24)	35 (28.23)	
Lymph nodes				0.51
pN0	30 (45.45)	19 (32.76)	49 (39.52)	
pN1	21 (31.82)	24 (41.38)	45 (36.29)	
pN2	8 (12.12)	9 (15.52)	17 (13.71)	
pN3	7 (10.61)	6 (10.34)	13 (10.48)	
Adjuvant chemotherapy	24 (36.36)	35 (60.34)	59 (47.58)	0.01†
Neoadjuvant chemotherapy	37 (56.06)	34 (58.62)	71 (57.26)	0.77
Endocrine therapy	32 (48.48)	20 (34.48)	52 (41.94)	0.11
Radiotherapy target				0.28‡
Chest wall	6 (9.09)	2 (3.45)	8 (6.45)	
Chest wall + lymph nodes	60 (90.91)	56 (96.55)	116 (93.55)	
Boost	57 (86.36)	49 (84.48)	106 (85.48)	0.77
Bolus	62 (93.94)	42 (72.41)	104 (83.87)	<0.01†
	n Mean (SD)	n Mean (SD)	n Mean (SD)	
Age at mastectomy, y	66 62.62 (12.47)	58 48.19 (10.18)	124 55.87 (13.51)	<0.01†
BMI, kg/m^2	66 28.52 (6.77)	58 30.28 (6.81)	124 29.34 (6.82)	0.15

*Chi-square test excludes missing values.
†Significant at $\alpha = 0.05$ level.
‡The Fisher exact test *P* value.

Table 3. Complications in Mastectomy Alone Versus Mastectomy + TE Implant for Immediate Breast Reconstruction

Complication	Mastectomy Only		Mastectomy + Reconstruction		*P*
Radiation dermatitis	59 (89.4%)		53 (91.4%)		0.769
Radiation pneumonitis	1 (1.5%)		2 (3.4%)		0.599
Cardiology adverse events	Before radiation	After radiation	Before radiation	After radiation	
Coronary artery disease	3	3	3	4	0.705
Pericarditis	0	0	0	1	0.468

demonstrate no statistically significant differences in rates of radiation dermatitis, radiation pneumonitis, or cardiac complications between the mastectomy-only and mastectomy + reconstruction groups following radiation therapy.

Magnetic Ports

Patients with breast reconstruction undergoing radiation are at risk for adverse events such as capsular contracture and wound healing complications. A 2-stage reconstruction using temporary TEs (TTEs) is often used.[12] Most TTEs have a magnetic port through which saline is injected to expand it during surgery and subsequent filling sessions. At our institution, we used single-port TTEs for our patients. Several studies have investigated the dosimetric impact of single-port TTEs on radiation plans with varying results. Some studies report between 5% and 30% dose perturbations, whereas some reported negligible differences.[13–15] Magnetic fill ports often contain high-density metal materials, which may cause scattering of the radiation beams and cause a phenomenon called "dose shadowing," which reduces the

Table 4. OAR Volumes and Radiation Doses, by Radiotherapy Target and Mastectomy Procedure

OAR Metrics, Median (IQR)	CW			CW + LNs			
	Mastectomy (n = 6)	Mastectomy + Reconstruction (n = 2)	Overall (n = 8)	Mastectomy (n = 60)	Mastectomy + Reconstruction (n = 56)	Overall (n = 116)	*P*
Lung							
Volume, cm^3	2209.65 (2120.00–2217.70)	2123.95 (2089.29–2158.61)	2183.21 (2104.65–2214.60)	1954.25 (1595.05–2381.97)	1989.33 (1811.25–2482.96)	1979.70 (1659.50–2419.05)	0.47
Minimum dose, Gy	0.20 (0.16–0.69)	0.07 (0.00–0.15)	0.16 (0.11–0.46)	0.34 (0.20–0.64)	0.36 (0.23–0.75)	0.35 (0.21–0.70)	0.59
Maximum dose, Gy	51.99 (50.81–54.59)	49.68 (49.14–50.22)	51.39 (49.68–53.31)	52.17 (50.97–55.90)	51.70 (50.87–52.55)	51.89 (50.88–53.47)	0.14
Mean dose, Gy	12.63 (9.10–13.97)	9.14 (7.12–11.16)	11.63 (8.89–13.56)	15.12 (13.49–16.66)	15.97 (14.55–17.72)	15.72 (13.64–17.27)	0.05
V20Gy, %	23.91 (22.62–27.08)	17.50 (12.82–22.18)	23.10 (18.88–25.66)	28.35 (24.68–31.29)	29.48 (26.69–33.31)	28.95 (25.26–32.33)	0.11
Heart							
Volume, cm^3	416.50 (394.20–552.90)	615.66 (571.21–660.11)	487.15 (402.90–615.66)	544.65 (465.75–611.45)	559.72 (493.80–651.05)	550.90 (476.48–634.10)	0.31
Minimum dose, Gy	0.27 (0.03–0.54)	0.05 (0.01–0.09)	0.09 (0.02–0.49)	0.22 (0.09–0.32)	0.21 (0.06–0.41)	0.22 (0.07–0.36)	0.99
Maximum dose, Gy	7.50 (5.42–15.69)	15.86 (6.27–25.45)	7.50 (5.85–20.57)	22.52 (7.11–35.93)	15.70 (6.75–35.54)	19.19 (6.79–35.72)	0.66
Mean dose, Gy	1.19 (0.69–2.09)	0.79 (0.52–1.06)	1.00 (0.61–1.76)	1.54 (1.00–2.28)	1.71 (0.97–2.46)	1.64 (0.97–2.33)	0.68
V25Gy, %	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.06)	0.00 (0.00–0.02)	0.00 (0.00–0.04)	0.31

Significant at $\alpha = 0.05$ level.

Table 5. CTV and Rib Cage Metrics, by Radiotherapy Target and Mastectomy Procedure

CTV and Rib Cage Metrics, Median (IQR)	CW			CW + LNs			
	Mastectomy (n = 6)	Mastectomy + Reconstruction (n = 2)	Overall (n = 8)	Mastectomy (n = 60)	Mastectomy + Reconstruction (n = 56)	Overall (n = 116)	*P*
CTV							
CTV, cm^3	289.95 (266.20–765.20)	654.28 (420.70–887.85)	357.15 (276.25–811.70)	488.55 (343.74–674.12)	1015.10 (728.36–1209.54)	688.63 (435.54–1015.10)	<0.01*
CTV mean dose, Gy	52.33 (51.11–54.24)	49.27 (48.95–49.59)	51.18 (50.08–53.83)	51.45 (50.81–52.12)	51.56 (51.09–52.37)	51.50 (50.88–52.14)	0.31
V95%, %	95.16 (91.43–98.65)	94.06 (93.05–95.06)	94.36 (92.24–97.66)	95.67 (93.59–98.41)	98.04 (95.55–99.46)	96.99 (94.66–99.00)	<0.01*
V95%, cm^3	272.61 (263.46–675.29)	613.03 (399.92–826.14)	338.35 (265.95–739.50)	464.85 (338.90–647.57)	980.14 (723.35–1108.40)	647.57 (422.88–980.14)	<0.01*
V105%, %	25.04 (8.81–43.29)	3.80 (0.04–7.56)	15.00 (4.12–36.09)	15.69 (6.67–27.79)	16.30 (5.78–30.80)	16.16 (6.54–28.31)	0.92
V105%, cm^3	72.46 (23.45–331.26)	33.65 (0.17–67.12)	64.67 (12.57–206.99)	61.55 (31.64–143.57)	111.02 (48.84–315.85)	81.83 (37.73–230.80)	0.01*
Rib cage							
Transverse diameter, cm	23.60 (22.39–24.50)	24.43 (23.46–25.39)	23.76 (22.77–24.95)	21.70 (20.34–23.13)	24.26 (23.47–24.88)	23.18 (21.51–24.41)	<0.01*
Anteroposterior diameter, cm	11.24 (10.32–11.86)	11.03 (10.19–11.87)	11.24 (10.26–11.87)	9.33 (8.21–9.96)	10.57 (9.46–11.45)	9.66 (8.73–10.90)	<0.01*
Ipsilateral internal diameter, cm	16.80 (14.81–18.03)	16.81 (16.62–17.00)	16.81 (15.39–17.84)	14.03 (12.81–14.97)	15.92 (14.86–16.66)	14.86 (13.58–16.08)	<0.01*
CWi	2.14 (2.03–2.32)	2.23 (1.98–2.49)	2.14 (2.00–2.41)	2.40 (2.21–2.65)	2.29 (2.15–2.53)	2.34 (2.16–2.63)	0.20

*Significant at $\alpha = 0.05$ level.

dose to the target tissue directly behind the port, or a "hot spot," which slightly increases the dose at the edges of the port due to the scattering effects.[13] No studies have yet investigated the effect of magnetic single-port TTEs on radiation to OARs. Our research suggests that magnetic single-port TTEs can be safely used during radiation, independent of patient morphological characteristics such as BMI and CWi.

Fill Volumes

TTEs are typically used to expand the breast tissue before implantation of permanent implants in breast

Table 6. Unadjusted Effects of Mastectomy Procedure, Mastectomy Side, and CWi on Lung Radiation Exposure, by Radiotherapy Target

	CW		CW + LNs			
Predictor	Lung V20Gy ≤ 30%, n %)	Lung V20Gy > 30%, n (%)	Lung V20Gy ≤ 30%, n (%)	Lung V20Gy > 30%, n (%)	OR (95% CI)	*P*
Mastectomy procedure						
Mastectomy + reconstruction	2 (100.00)	0 (0.00)	34 (60.71)	22 (39.29)	0.90 (0.42–1.90)	0.77
Mastectomy	6 (100.00)	0 (0.00)	38 (63.33)	22 (36.67)	1.00 (REF)	—
Mastectomy side						
Bilateral	0 (0.00)	0 (0.00)	36 (63.16)	21 (36.84)	1.71 (0.71–4.12)	0.23
Left	3 (100.00)	0 (0.00)	20 (74.07)	7 (25.93)	2.86 (0.95–8.63)	0.06
Right	5 (100.00)	0 (0.00)	16 (50.00)	16 (50.00)	1.00 (REF)	—
CWi						
CWi > 2.32	2 (100.00)	0 (0.00)	36 (60.00)	24 (40.00)	0.83 (0.39–1.77)	0.63
CWi ≤ 2.32	6 (100.00)	0 (0.00)	36 (64.29)	20 (35.71)	1.00 (REF)	—

Significant at α = 0.05 level.
CI, confidence interval; OR, odds ratio; REF, reference.

Table 7. Unadjusted Effects of Mastectomy Procedure, Mastectomy Side, and CWi on Heart Radiation Exposure, by Radiotherapy Target

	CW		CW + LNs			
Predictor	Heart Mean, Dose ≤ 5 Gy, n (%)	Heart Mean, Dose > 5 Gy, n (%)	Heart Mean, Dose ≤ 5 Gy, n (%)	Heart Mean, Dose > 5 Gy, n (%)	OR (95% CI)	*P*
Mastectomy procedure						
Mastectomy + reconstruction	2 (100.00)	0 (0.00)	55 (98.21)	1 (1.79)	2.89 (0.29–28.68)	0.36
Mastectomy	6 (100.00)	0 (0.00)	57 (95.00)	3 (5.00)	1.00 (REF)	—
Mastectomy side						
Bilateral	0 (0.00)	0 (0.00)	55 (96.49)	2 (3.51)	0.89 (0.08–10.18)	0.92
Left	3 (100.00)	0 (0.00)	26 (96.30)	1 (3.70)	0.84 (0.05–14.08)	0.90
Right	5 (100.00)	0 (0.00)	31 (96.88)	1 (3.13)	1.00 (REF)	—
CWi						
CWi > 2.32	2 (100.00)	0 (0.00)	57 (95.00)	3 (5.00)	0.35 (0.04–3.42)	0.36
CWi ≤ 2.32	6 (100.00)	0 (0.00)	55 (98.21)	1 (1.79)	1.00 (REF)	—

Significant at α = 0.05 level.
CI, confidence interval; OR, odds ratio.

reconstruction. Studies have shown inconsistent outcomes when investigating TTE fill volume and complication rates. A study by Yazar et al[16] analyzed complications of Becker-type expanders and found that intraoperative fill volume seemed to be a predictor of developing capsular contracture. Kadakia et al[17] found that larger saline fill volumes greater than 350 mL were not associated with postoperative complications. Although some studies evaluated complication risks with varying TTE fill volumes, their effects on PMRT are limited in the literature. Our research is the first to support that varying fill volume does not impact radiation to the OARS.

CW Geometry

Our study was designed to detect whether certain patient factors that affect the geometry of the chest such as BMI, CWi, and resection weight could affect PMRT delivery in women with TEs. We did not find significant differences with regard to these factors except for BMI. Higher BMI correlated with increased maximum heart dose, which may influence radiotherapy timing decisions for high-BMI patients.

Boost/Bolus

In PMRT, a bolus is a material placed on the skin to modify the distribution of dose delivered to the underlying and surrounding tissues. It is widely recommended that the target area should receive at least 95% of the predesigned PMRT dose. However, superficial targets often cannot receive a sufficient dose due to the skin-sparing effect of high-energy photon beams. Boluses are predominantly used to provide a "dose buildup," intensifying the radiation delivered to underlying structures and minimizing the risk of underdosing target areas.[18] Boluses come at a risk of a higher rate of acute grade 3 radiation dermatitis, which must be considered when evaluating skin integrity.[19] In our study, patients with immediate reconstruction with TTEs were significantly less likely to receive a bolus.

Boosts refer to an additional, localized dose of radiation that is delivered to or around the primary target field. They are often used to treat residual areas or to compensate for decreasing dosages as the radiation penetrates tissue.[20] In our study, there were no differences in boost use between patients with immediate or delayed reconstruction with TTEs.

Table 8. Radiotherapy Metrics Among Patients Undergoing Mastectomy + Reconstruction, by Radiotherapy Target and Intraoperative Expander Fill Volume

Radiotherapy Metric, Median (IQR)	CW			CW + LNs			
	≤ 60 mL Fill Volume (n = 1)	> 60 mL Fill Volume (n = 1)	Overall (n = 2)	≤ 60 mL Fill Volume (n = 21)	> 60 mL Fill Volume (n = 35)	Overall (n = 56)	*P*
Lung							
Minimum dose, Gy	0.15 (0.15–0.15)	0.00 (0.00–0.00)	0.07 (0.00–0.15)	0.30 (0.14–0.75)	0.41 (0.23–0.76)	0.36 (0.23–0.75)	0.45
Maximum dose, Gy	49.14 (49.14–49.14)	50.22 (50.22–50.22)	49.68 (49.14–50.22)	51.60 (51.12–51.90)	51.93 (50.76–53.44)	51.70 (50.87–52.55)	0.51
Mean dose, Gy	11.16 (11.16–11.16)	7.12 (7.12–7.12)	9.14 (7.12–11.16)	15.87 (14.99–17.70)	16.22 (13.91–17.73)	15.97 (14.55–17.72)	0.93
V20Gy, %	22.18 (22.18–22.18)	12.82 (12.82–12.82)	17.50 (12.82–22.18)	29.28 (26.97–33.95)	29.52 (26.24–33.29)	29.48 (26.69–33.31)	0.98
Heart							
Minimum dose, Gy	0.01 (0.01–0.01)	0.09 (0.09–0.09)	0.05 (0.01–0.09)	0.16 (0.06–0.39)	0.26 (0.07–0.42)	0.21 (0.06–0.41)	0.78
Maximum dose, Gy	6.27 (6.27–6.27)	25.45 (25.45–25.45)	15.86 (6.27–25.45)	15.96 (7.32–33.87)	14.55 (6.53–39.87)	15.70 (6.75–35.54)	0.97
Mean dose, Gy	0.52 (0.52–0.52)	1.06 (1.06–1.06)	0.79 (0.52–1.06)	1.66 (1.02–2.23)	1.87 (0.96–2.46)	1.71 (0.97–2.46)	0.95
V25Gy, %	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.02)	0.00 (0.00–0.04)	0.00 (0.00–0.02)	0.89
CTV							
CTV, cm^3	887.85 (887.85–887.85)	420.70 (420.70–420.70)	654.28 (420.70–887.85)	915.00 (692.51–1083.00)	1097.30 (833.00–1249.90)	1015.10 (728.36–1209.54)	0.09
CTV mean dose, Gy	48.95 (48.95–48.95)	49.59 (49.59–49.59)	49.27 (48.95–49.59)	51.34 (50.81–51.87)	51.75 (51.24–52.51)	51.56 (51.09–52.37)	0.11

Significant at $\alpha = 0.05$ level.

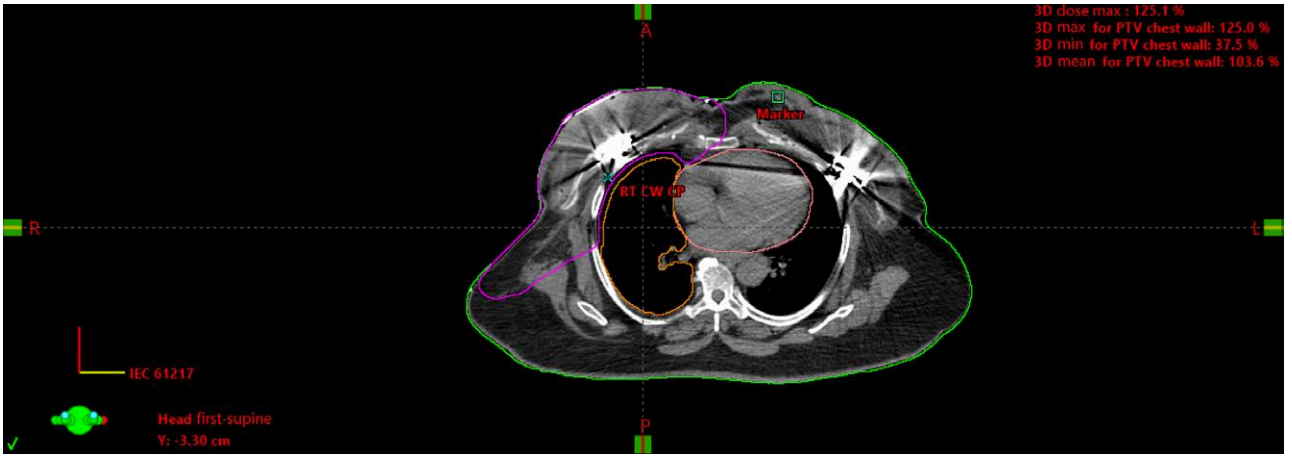

Fig. 2. Patient with 600 mL intraoperative tissue expander saline fill. RT, radiation therapy. PTV, planning target volume; RT CW CP, right chest wall clinical plan.

Study Limitations

Our study has several limitations. The retrospective nature made tracking specific patient information difficult, specifically the TTE fill volumes and practice patterns. Fill volume determination varied by surgeon discretion, leading to inconsistencies in timing and extent of expansion at the start of PMRT. Although we attempted to track these filling patterns as closely as possible to the radiation start dates, the variability in practice patterns must be considered when evaluating these data.

Our decision to dichotomize TE fill volumes into 60 mL or less and greater than 60 mL, rather than as a continuous variable was driven by the distribution of fill volumes within our patient population. Patients receiving immediate breast reconstruction were typically managed in 1 of 2 categories: (1) 60 mL or less (predominantly 60 or 0 mL in cases where expanders were left unfilled), and (2) greater than 60 mL(expanders were filled beyond 60 mL) (Fig. 2). Dichotomization at this threshold enabled us to evaluate clinically relevant differences in radiation dose metrics between these 2 categories.

In addition, although radiation dermatitis presents shortly after radiation therapy, radiation pneumonitis or cardiac complications such as coronary artery disease,

cardiomyopathy, and arrhythmias may form years to decades after radiation therapy, which would not be captured in our data analysis. Longitudinal studies that capture these complication rates would be a useful adjunct when evaluating the safety of radiation therapy.

The use of bolus and boost techniques in PMRT was not fully explored in this study. Although we found that patients with immediate reconstruction had a lower likelihood of receiving a bolus, the underlying reasons for the finding and clinical implications warrant further investigation. The presence of a TTE may make it challenging to achieve proper dose buildup or may lead to increased tension on the skin and underlying tissue; thus, bolus may be avoided by radiation oncology teams.[18,19] These themes should be explicitly explored in future research.

CONCLUSIONS

Our study demonstrates that the presence of TEs with magnetic ports and varying intraoperative fill volumes do not significantly affect radiation dose distribution or complication rates to the heart and lungs during PMRT. Immediate breast reconstruction with TEs can be safely performed without compromising radiation treatment plans. However, increased BMI correlated with a higher maximum heart dose, which may be a consideration for high-BMI patients. These findings support the safety of immediate breast reconstruction with TEs in the context of planned PMRT, potentially allowing more patients to benefit from immediate reconstruction without compromising oncological treatment.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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