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BREAST

An Innovative Risk-Reducing Approach to Postmastectomy Radiation Delivery after Autologous Breast Reconstruction

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Introduction: Postmastectomy radiation therapy (PMRT) has known deleterious side effects in immediate autologous breast reconstruction. However, plastic surgeons are rarely involved in PMRT planning. Our institution has adopted a custom bolus approach for all patients receiving PMRT. This offers uniform distribution of standard radiation doses, thereby minimizing radiation-induced changes while maintaining oncologic safety. We present our 8-year experience with the custom bolus approach for PMRT delivery in immediate autologous breast reconstruction.
Methods: All immediate autologous breast reconstruction patients requiring PMRT after 2006 were treated with the custom bolus approach. Retrospective chart review was performed to compare the postirradiation complications, reconstruction outcomes, and oncologic outcomes of these patients with those of previous patients at our institution who underwent standard bolus, and to historical controls from peer-reviewed literature.
Results: Over the past 10 years, of the 29 patients who received PMRT, 10 were treated with custom bolus. Custom bolus resulted in fewer radiation-induced skin changes and less skin tethering/fibrosis than standard bolus (0% vs 10% and 20% vs 35%, respectively), and less volume loss and contour deformities compared with historical controls (10% vs 22.8% and 10% vs 30.7%, respectively).
Conclusions: Custom bolus PMRT minimizes radiation delivery to the internal mammary vessels, anastomoses, and skin; uniformly doses the surgical incision; and provides the necessary radiation dose to prevent recurrence. Because custom bolus PMRT may reduce the deleterious effects of radiation on reconstructive outcomes while maintaining safe oncologic results, we encourage all plastic surgeons to collaborate with radiation oncologists to consider this technique. *(Plast Reconstr Surg Glob Open 2017;5:e1265; doi: 10.1097/GOX.0000000000001265; Published online 25 April 2017.)*

The increasing use of total skin-sparing mastectomy and nipple-sparing mastectomy in the United States has led to higher rates of mastectomy for treating and preventing breast cancer, as these techniques offer improved aesthetic outcomes.[1] A corresponding rise in immediate breast reconstruction has paralleled this trend. Autologous breast reconstruction is a popular option given its excellent aesthetic results[2–4] and positive patient reported and clinical outcomes.[4–6] After mastectomy, many women require radiation therapy to complete their cancer treatment, as a way to decrease locoregional recurrence.[7–9] However, there is little consensus among radiation oncologists regarding the optimal delivery fields and dosages of postmastectomy radiotherapy (PMRT) for the many women who undergo immediate autologous tissue-based reconstruction.[10–13]

There is conflicting evidence about the ability of autologous flaps to tolerate PMRT.[14–20] Radiation therapy has

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numerous potential deleterious effects on autologous tissue flaps, and on the appearance and feel of the overall reconstruction. These include mild to severe erythema, hyperpigmentation, desquamation, fat necrosis, volume loss, fibrosis, flap contracture, and vascular thrombosis.[18,20–25] As a result, irradiation of the flap may result in breast asymmetry and an inferior overall aesthetic outcome.[18,25–27]

Despite the significant impact of radiation on autologous reconstruction, plastic surgeons are seldom involved in the decision-making process regarding radiation therapy delivery. At our institution, plastic surgeons always maintain an open dialogue with radiation oncologists for radiation planning and delivery so as to optimize outcomes and minimize radiation's deleterious effects.

In this study, we present our experience with custom bolus PMRT, used to minimize deleterious effects to the reconstructed autologous breast mound. With standard bolus techniques, air gaps can lead to dose inhomogeneity that may lead to "hot spots," thus resulting in overdoses of radiation to the skin in those areas. Custom bolus PMRT improves dose homogeneity involving the skin and subcutaneous tissues by conforming to the individual's contour, thereby leading to fewer complications.[28] Though it has been shown to be effective in prior literature,[28] radiation oncologists do not widely use custom bolus.[12] This may be explained by the initial time investment of designing the mold and planning the radiation delivery. At our institution, we have adopted custom bolus as the standard of care for all patients receiving PMRT. The following details our clinical outcomes over the past 8 years and compares them with outcomes before adoption of custom bolus, and with outcomes presented in peer-reviewed literature.

METHODS

Patient Selection

We reviewed the records of all patients with breast cancer who underwent mastectomy with immediate autologous reconstruction at our institution from 2005 to 2014. A total of 157 patients (226 breasts) were identified. Of these, 29 patients received PMRT, including 10 treated using our customized approach. Charts were retrospectively reviewed for patient demographics, operative reports, and radiation therapy details. Medical records of all included patients were reviewed in 2015 to ensure no complications were missed. This study was approved by the University of California, San Francisco Committee on Human Research.

Surgical Technique

All patients had modified-radical, skin-sparing, or total skin-sparing mastectomy (complete nipple/areolar external skin preservation and internal inversion of the nipple with aggressive excision of all nipple parenchyma to the dermal junction). Incisions used for total skin-sparing mastectomy included inframammary, superior periareolar, and other incisions (lateral, radial, and incisions that incorporated prior breast surgery scars). Autologous breast reconstruction options included pedicled transverse rectus abdominis myocutaneous (TRAM) flap, muscle-sparing TRAM free flap, or deep inferior epigastric perforator free flap.

Radiation Therapy

Radiation was delivered to the reconstructed autologous breast in 29 patients. After 2006, 10 patients received our custom bolus method by a single radiation oncologist (BF), whereas the remaining 19 patients received the standard bolus method. The custom bolus uses perforated Aquaplast and a nearly tissue-equivalent wax (Kindt-Collins, Cleveland, OH). First, perforated Aquaplast is heated and stretched over the reconstructed chest wall. Tissue equivalent wax is then heated and strips are placed over the Aquaplast. As the wax cools, it hardens and conforms to the irregular contours of the chest wall (Fig. 1). Total time for creation of the Aquaplast mold is 15 minutes, and materials' cost is $100 per patient. This wax cast retains its molded shape, allowing for easy application throughout the duration of treatment, thus minimizing air gaps and consequently dose inhomogeneity.[28]

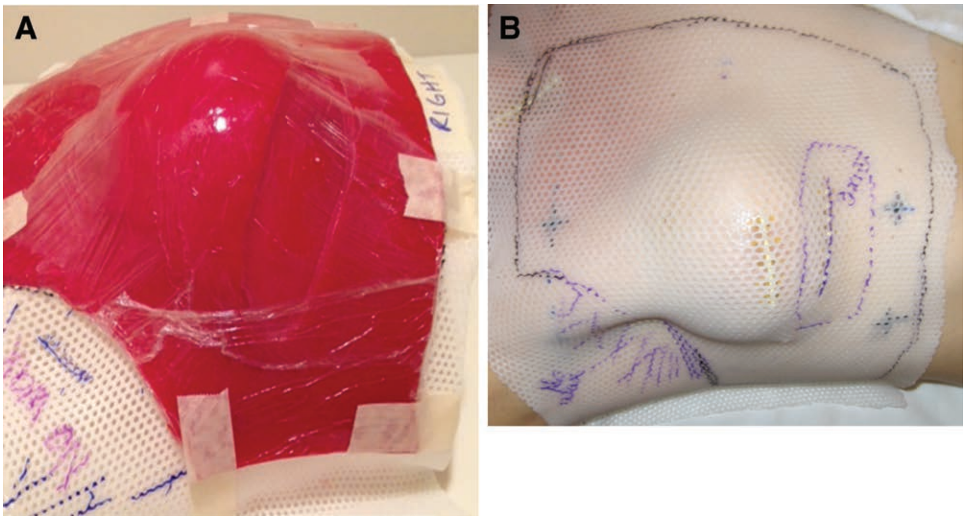

Fig. 1. Fabrication of custom bolus using perforated Aquaplast (A), which is then covered by tissue-equivalent wax (B) to form a hard cast contoured to the irregularities of the reconstructed chest wall.

The custom bolus radiation regimen consisted of opposed tangential fields to the breast using 6-MV or 6/18-MV photons with the field-in-field technique. Five hours of labor are typically needed per patient to construct the bolus. The cost of constructing the bolus depends on the salary of the person doing the construction, who is typically a technician. A custom bolus of 5 mm was used every-other-day with 3 mm over central or inframammary surgical scars. No boost to the mastectomy scar was given. Prophylactic radiation was not delivered to the internal mammary nodes unless patients had positive nodes documented by imaging or biopsy (Fig. 2).

The location of the internal mammary anastomosis was marked intraoperatively with clips, so the radiation oncologist could limit radiation to this area if possible without compromising coverage of the targeted regions. Patients received radiation to the supraclavicular region if 4 or more positive axillary nodes were identified. On non-bolus days (treatment given but no bolus used), film dosimeter readings were obtained, and on bolus days, optical luminescent dosimeter readings were used to assess adequacy of the radiation plan.

Total radiation delivered was 5000–5040 cGy administered in 180–200 cGy fractions per day for 5 days a week over a 5- to 6-week period. Standard fractionation was used. Surface dose was measured with film dosimeters on non-bolus days and optical luminescent dosimeters on bolus days to confirm that the superficial doses being delivered were adequate to control microscopic disease. No patients with gross disease were treated.

Outcomes

Retrospective chart review was performed, and the following complications were recorded: infection, wound dehiscence, nipple necrosis, skin flap necrosis, unplanned return to the operating room, and flap loss. Additionally, all charts were reviewed for radiation-specific complications, namely skin changes, fat necrosis, breast asymmetry/volume loss, pain, and severe scarring and tethering. Infection was divided into those treated with oral versus those treated with intravenous antibiotics. We defined nipple necrosis as either partial or complete loss of the nipple areola complex skin. Mastectomy skin flap necrosis was defined as either partial- or full-thickness loss of breast skin. Local and distant cancer recurrences after radiation therapy were also recorded.

We used the Radiation Therapy Oncology Group (RTOG) and European Organization for Research and Treatment of Cancer (EORTC) acute radiation toxicity grading system for evaluating radiation-induced skin changes.[29] Skin changes were documented if they were considered grade III (confluent, moist desquamation other than skin folds, pitting edema) or higher. Fat necrosis was defined as clinically significant fat necrosis, which was

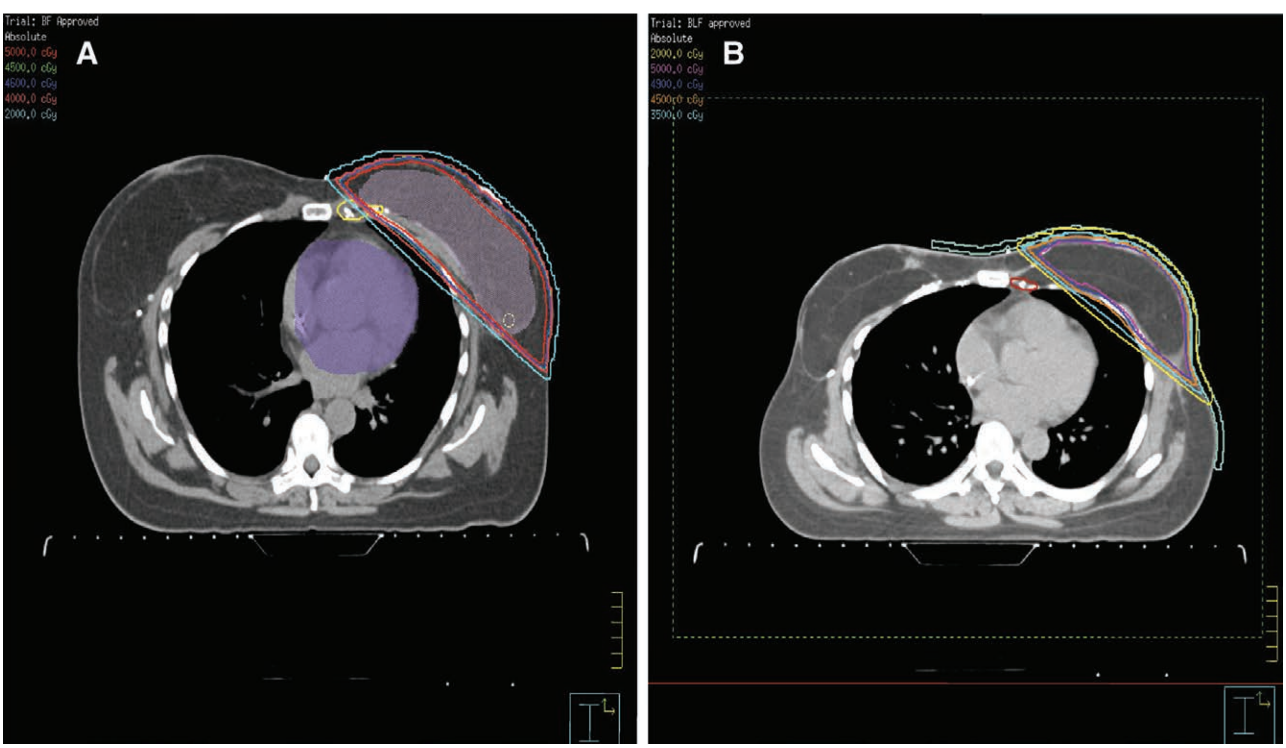

Fig. 2. A, Isodose curves for a 55-year-old woman with stage IIA carcinoma of the left breast and a positive sentinel node. She received PMRT to the left DIEP reconstructed breast and supraclavicular region. The vascular clips at the DIEP anastomosis are outlined in yellow. Some of the clips are in the radiation field, outlined in red, with a dose of 50 Gy. Although the anastomosis was not completely excluded from radiation, the dose was much lower than that prescribed for the tumor. B, Isodose curves for a 42-year-old woman with stage IV carcinoma of the left breast and extensive recurrent axillary disease. She received PMRT to the left DIEP reconstructed breast, axilla, and supraclavicular area. The vascular clips of the DIEP anastomosis are outlined in red. The anastomosis was outside the higher doses of the radiation fields.

palpable during postoperative evaluation and often required surgical excision.

The outcomes from the subset of 10 patients (10 breasts) treated with custom bolus were compared with those of the 19 additional patients (20 breasts) at our institution who were treated with standard PMRT. As a way to qualify our data against other institutions, we performed a literature search using PubMed to compare our results against historical controls. We sought out articles that specifically evaluated outcomes of postmastectomy radiation therapy on autologous breast reconstruction. Search terms included "autologous tissue reconstruction," "breast reconstruction," "postmastectomy radiation therapy," "adjuvant radiation therapy," and a combination of the above. References from selected articles were reviewed to identify additional articles. Articles were excluded if they did not include pertinent complications, did not stratify by method of reconstruction, or had less than 1 year of follow-up. If multiple studies were published from the same group, only the most recent study was used. Ultimately 11 articles were used for comparison.[18,22,23,25,26,30–35]

RESULTS

Patient and Treatment Characteristics

Between 2005 and 2015, 157 patients (226 breasts) underwent immediate autologous tissue breast reconstruction after mastectomy at our institution. Of these, 29 patients (18.5%) received PMRT, and 10 patients (34.5%) of these were treated with our customized approach (Fig. 3). Patients were similar with regard to age, body mass index, smoking status, medical comorbidities, chemotherapy, previous breast radiation, clinical stage, pathologic stage, or estrogen receptor/progesterone receptor status (Table 1). However, notably more patients in the custom bolus group received hormone therapy and were HER2+. Most patients (83.3%) had pedicled TRAM reconstruction (Table 2).

Outcomes

We found clinically that patients who had custom bolus trended toward lower rates of nipple loss, fewer radiation-induced skin changes, and decreased excessive scarring compared with patients who had standard bolus radiation delivery (Table 3). In terms of early complications, custom bolus patients in our study trended to lower clinical rates of skin flap necrosis and delayed wound healing. In terms of late complications, custom bolus patients in our study showed clinical trends to less volume loss and contour deformity.

Mean follow-up for the custom bolus cohort was 62.8 months, with the range from 14.2 to 101.2 months. Mean follow-up for the standard bolus cohort was 59.9 months, with the range from 9.4 to 101.4 months. No patients had local recurrence in the custom bolus group. One patient had local recurrence in the standard bolus group at the level of the skin, and was treated with re-excision. One patient in the custom bolus cohort developed metastatic disease, and 2 patients in the standard bolus group developed metastatic disease. Two of these patients are still alive, and 1 was lost to follow-up.

Comparison of radiation-specific complications across the 11 articles from our literature review indicated significant variability in reported outcomes (Table 4). Flap loss was the most frequently reported outcome, and rates were low (0%–1.6%) in all studies. Three studies[22,26,31] predominantly used pedicled TRAM flaps for reconstruction, similar to our institution. Of those 3 studies, only 1 study[26] reported fat necrosis rates, and these were comparable with our rates. Two studies[22,31] reported radiation-induced skin changes in 9.1% and 0% of patients, which were also comparable with our rates (10% in standard bolus, 0% in custom bolus).

Overall, volume loss, delayed wound healing, infection, and radiation-induced skin changes were reported in only 5 of the 11 studies, excessive scarring was reported in 2 of the 11 studies, and nipple necrosis was reported in only 1 study. These complications are often dramatically affected by radiation therapy, yet no study consistently reported them.

DISCUSSION

Traditionally, the decision to undergo immediate versus delayed reconstruction is strongly influenced by the need for PMRT. The 2014 ASPS Clinical Practice Guidelines cite that although evidence is limited, radiation acts as a

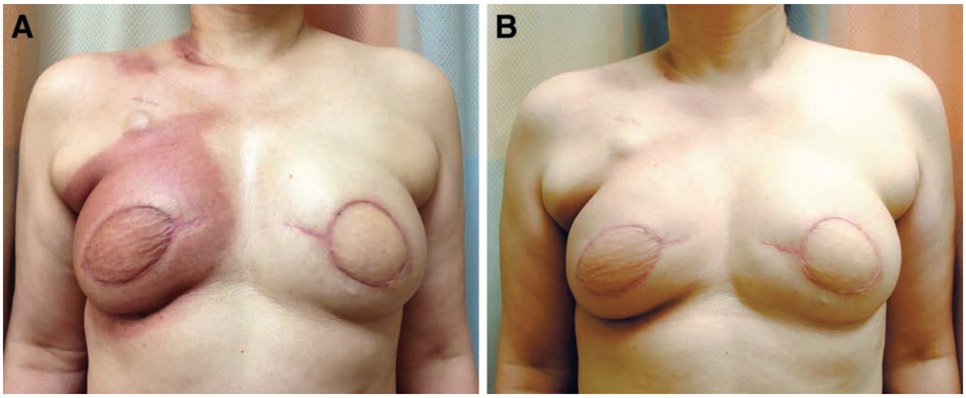

Fig. 3. Woman who had bilateral DIEP breast reconstructions underwent PMRT using custom bolus. A, One week after radiation therapy completed. B, Nine weeks after radiation therapy completed.

Table 1. Patient and Tumor Characteristics of Custom and Standard Bolus Patients

	Custom Bolus (n = 10)	Standard Bolus (n = 20)	*P*-value (Custom Bolus vs Standard Bolus)*	Mirzabeigi et al. (n = 127)	*P*-value (Custom Bolus vs Mirzabeigi et al.)*
Mean follow-up months	61.4	59.9	0.91†	23.2	—
Mean age (SD)	51.5 (6.0)	52.8 (8.1)	0.66†	47.1 (8.5)	0.15†
Mean BMI (SD)	28.9 (4.4)	28.4 (3.4)	0.73†	28.2 (5.7)	0.71†
Comorbidities					
Diabetes, n (%)	1 (10)	2 (10)	1.0	8 (6.3)	0.51
PVD, n (%)	0	0	1.0	1 (0.9)	1
CAD, n (%)	0	0	1.0	1 (0.9)	1
Hypertension, n (%)	4 (40)	2 (10)	0.14	29 (22.8)	0.25
COPD, n (%)	0	0	1.0	1 (0.9)	1
Hypercholesterolemia, n (%)	1 (10)	1 (5)	1.0	17 (13.4)	1
Smoking			0.69		
Former smoker, n (%)	4 (40)	6 (30)		—	—
Current smoker, n (%)	0	0		—	—
Chemotherapy			0.63		
Neoadjuvant, n (%)	8 (80)	15 (75)		—	—
Adjuvant, n (%)	1 (10)	5 (25)		—	—
Hormone therapy, n (%)	9 (90)	10 (50)	0.049§	—	—
Previous breast radiation, n (%)	1 (10)	1 (5)	1.0	0	0.073
Clinical stage			0.49		—
Stage 0, n (%)	0	0		—	
Stage 1, n (%)	1 (10)	0		—	
Stage 2, n (%)	6 (60)	12 (60)		—	
Stage 3, n (%)	3 (30)	8 (40)		—	
Stage 4, n (%)	0	0		—	
Pathological stage‡			0.48		—
Stage 0, n (%)	0	1 (5)		—	
Stage 1, n (%)	1 (10)	0		—	
Stage 2, n (%)	6 (60)	9 (45)		—	
Stage 3, n (%)	3 (30)	9 (45)		—	
Stage 4, n (%)	0	0		—	
Receptor status					
ER+, n (%)	10 (100)	14 (70)	0.074	—	—
PR+, n (%)	9 (90)	11 (55)	0.1	—	—
HER2+, n (%)	3 (30)	0	0.030§	—	—

*All using Fisher's exact test unless otherwise specified.
†*t* test.
‡One patient in the conventional cohort had a pathological complete response (pCR).
§*P*-values <0.05.
BMI, body mass index; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; ER, estrogen receptor; HER2, human epidermal growth factor receptor 2; PR, progesterone receptor; PVD, peripheral vascular disease.
—, not available.

confounding factor in the timing of expander/implant reconstruction.[36] The decision to perform immediate versus delayed autologous reconstruction in the setting of PMRT is even less-explored. PMRT is often the reason that many institutions delay autologous reconstruction,[37] even though PMRT has not been shown to significantly affect the revision rate for immediate autologous reconstruction.[23] As patients have been shown to prefer and benefit psychologically from immediate reconstruction,[37–40] further advances in PMRT (along with better coordination of care among plastic surgeons and radiation oncologists) may help simplify the decision about whether to perform immediate autologous reconstruction in this setting. Through this open dialogue, including anticipated radiation delivery dosages and length of treatment, reconstructive surgeons may be able to tailor individual decisions for each patient as to their best timing for reconstruction.

Surgeons and radiation oncologists differ in their awareness and attitudes toward PMRT, with most radiation oncologists reporting lack of early participation in treatment planning for breast cancer patients.[41] Though it can have major consequences on reconstructive outcomes, PMRT is often left to the jurisdiction of the radiation oncology team alone. Many radiation oncologists are not considering reconstructive procedures or flap physiology/anatomy when they plan and implement radiation delivery,[10] and thus may choose more aggressive protocols.

Radiation protocols vary widely between institutions and providers. The use of bolus is considered standard for postmastectomy radiation to prevent underdosing of the superficial tissues, and most major cancer centers in the United States use bolus.[42] Unfortunately, most papers do not report the exact radiation protocols used. This makes it challenging to compare outcomes after radiation between different institutions, which is one of the challenges we faced when comparing our 2 groups with historical controls.

Additionally, plastic surgeons are often unaware and uninvolved in the process. We think it is important for plastic surgeons and radiation oncologists to work collaboratively. Coordinating care early enables the plastic surgeon to gain a better understanding of the steps involved in developing a radiation plan, and the radiation oncologist to adapt the radiation protocol for future reconstruction. Therefore, great effort should be made to improve

Table 2. Surgical Characteristics of Custom and Standard Bolus Patients

	Custom Bolus (n = 10)	Standard Bolus (n = 20)	*P*-value (Custom Bolus vs Standard Bolus)*	Mirzabeigi et al. (n = 127)	*P*-value (Custom Bolus vs Mirzabeigi et al.)*
Mastectomy type			0.59		—
Non-skin-sparing, n (%)	2 (20)	3 (15)		—	
Skin-sparing, n (%)	5 (50)	7 (35)		—	
Total skin-sparing, n (%)	3 (30)	10 (5)		—	
Incision type			0.33		—
Inframammary, n (%)	2 (20)	4 (20)		—	
Superior areolar, n (%)	0	5 (25)		—	
Inferior periareolar, n (%)	4 (40)	5 (25)		—	
Radial, n (%)	0	2 (10)		—	
Other, n (%)	4 (40)	4 (20)		—	
Reconstruction			0.73		<0.001†
Pedicle TRAM, n (%)	8 (80)	17 (85)		0	
Free TRAM, n (%)	0	1 (5)		88 (69.3)	
DIEP, n (%)	2 (20)	2 (10)		28 (22.0)	
Other, n (%)	0	0		11 (8.7)	
Recipient vessel			1		0.23
Internal mammary, n (%)	2	3		58	
Thoracodorsal, n (%)	0	0		67	
Other, n (%)	0	0		1	

*All using Fisher's exact test.
†*P*-values <0.05.
DIEP, deep inferior epigastric perforator; TRAM, transverse rectus abdominis myocutaneous.
—, not available.

communication and encourage early participation among all members of the multidisciplinary breast cancer team.

A custom bolus approach to PMRT, which involves close collaboration with the radiation oncology team, limits radiation delivery to the incision and the vascular pedicle in autologous reconstruction, thereby reducing potential for PMRT complications such as vascular injury, skin changes, fat necrosis, and delayed wound healing. Our patients who received custom bolus tended to have fewer skin changes, contour irregularities, skin flap necrosis, and volume loss than patients who received standard bolus. Although the use of custom bolus will likely reduce fat necrosis rates in autologous reconstruction moving forward when routinely implemented, our fat necrosis rates were higher in the custom bolus population than in our institutional controls and other historical controls. We can attribute this to multiple factors: institutional, diagnostic, and patient related. First, institutional factors, including new faculty and strengthened relationships between departments, has led to more rigorous follow-up, physical examination, and documentation of outcomes. This translates to increased detection of clinical outcomes and morbidity, such as fat necrosis. Our institution also performed primarily pedicled TRAM flaps in the early portion of this study period, which in some studies have higher documented rates of fat necrosis.[43,44] This is no longer the case; since 2011 almost all the autologous reconstructions we perform are deep inferior epigastric perforator free DIEP

Table 3. Comparison of Specific Complications in Custom and Standard Bolus Patients with Those Reported by Mirzabeigi et al.

	Custom Bolus (n = 10)	Standard Bolus (n = 20)	*P*-value (Custom Bolus vs Standard Bolus)*	Mirzabeigi et al. (n = 127)	*P*-value (Custom Bolus vs Mirzabeigi et al.)*
Early complications					
Flap loss, n (%)	0	0	1	2 (1.6)	1
Cellulitis, n (%)	2 (20)	3 (15)	1	10 (7.9)	0.21
Skin flap necrosis, n (%)	0	1 (5)	1	25 (19.7)	0.21
Delayed wound healing, n (%)	4 (40)	4 (20)	0.38	62 (48.8)	0.75
Late complications					
Volume loss, n (%)	1 (10)	3 (15)	1	29 (22.8)	0.69
Contour deformity, n (%)	1 (10)	3 (15)	1	39 (30.7)	0.28
Fat necrosis, n (%)	4 (40)	5 (25)	0.43	21 (16.5)	0.08
Nipple necrosis, n (%)	0	2 partial (10)	0.54	—	—
Skin changes, n (%)	0	2 (10)	0.54	—	—
Axillary cording/scarring, n (%)	2 (20)	7 (35)	0.67	—	—
Revision surgery					
Implants, n (%)	1 (10)	0	0.33	8 (6.3)	0.51
Fat grafting, n (%)	0	0	1	13 (10.2)	0.60
Breast liposuction, n (%)	1 (10)	3 (15)	1	9 (7.1)	0.54
Local tissue rearrangement, n (%)	2 (20)	5 (25)	1	43 (33.9)	0.50

—, not available.
*All using Fisher's exact test.

Table 4. Comparison of General Complications in Custom and Standard Bolus Patients with Those in Historical Controls

	Custom Bolus (n = 10)	Standard Bolus (n = 20)	Carlson et al. (n = 25)	Chatterjee et al. (n = 22)	Clarke et al. (n = 11)	Foster et al. (n = 35)	Huang et al. (n = 82)	Lee et al. (n = 59)	Mehta et al. (n = 22)	Mirzabeigi et al. (n = 127)	Rogers et al. (n = 30)	Soong et al. (n = 25)	Tran et al. (n = 32)
Volume loss, n (%)	1 (10)	3 (15)	—	3 (13.6)	—	2 (5.7)	—	—	—	29 (22.8)	17 (56.7)	—	28 (87.5)
Skin necrosis, n (%)	0	1 (5)	3 (12)	—	—	—	—	—	—	25 (19.7)	—	0	3 (9.4)
Nipple necrosis, n (%)	0	2 partial (10)	—	—	—	—	—	—	—	—	—	0	—
Delayed wound healing, n (%)	4 (40)	4 (20)	—	—	1 (9.1)	—	—	—	—	62 (48.8)	11 (36.7)	0	—
Flap loss, n (%)	0	0	0	—	0	0	0	0	0	2 (1.6)	0	0	0
Fat necrosis, n (%)	4 (40)	5 (25)	8 (32)	—	0	3 (8.6)	7 (8.5)	—	—	21 (16.5)	7 (23.3)	—	14 (43.8)
Contour deformity, n (%)	1 (10)	3 (15)	—	—	3 (27.3)	—	—	—	—	39 (30.7)	—	—	24 (75)
Cellulitis, n (%)	2 (20)	3 (15)	0	—	—	2 (5.7)	—	—	1 (4.5)	10 (7.9)	5 (16.7)	—	—
Skin changes, n (%)	0	2 (10)	—	—	1 (9.1)	—	8 (9.8)	—	2 (9.1)	—	—	0	—
Axillary cording/scarring, n (%)	2 (20)	7 (35)	—	—	—	—	—	—	—	—	—	—	—

—, not available.

flaps. Second, diagnosis of fat necrosis is subjective, varies considerably between clinicians, and is inconsistently documented. Comparing outcomes between different institutions and historical literature is subjective,[20] due to these inconsistencies. Finally, patient factors, including other risk factors for fat necrosis, such as obesity and smoking, as well as inconsistent follow-up and variable symptoms affect the ability to detect and compare outcomes.[44]

Additionally, our sample sizes are small, which makes drawing definitive conclusions difficult. This is because in the past we seldom performed immediate autologous reconstruction in patients who required PMRT. Our philosophy has changed though, and we believe autologous tissue flaps tolerate radiation better than mastectomy skin flaps over prosthetic devices, and consequently, are performing more autologous reconstructions when PMRT is anticipated.

Another potential limitation of our study is its retrospective nature. Ideally, we would prospectively evaluate how different radiation protocols influenced postmastectomy immediate autologous reconstruction. However, the feasibility of accomplishing this is limited by the fact that relatively few women who undergo immediate autologous reconstruction will require radiation therapy. Additionally, custom bolus is now the standard of care for our busiest radiation oncologist. Our current practice is to use custom bolus and targeted radiation delivery to all our immediate free flap breast reconstructions. With these changes, we are experiencing lower fat necrosis rates and fewer complications in these individuals. Future research is directed toward evaluating aesthetic outcomes and complications in immediate autologous reconstruction versus delayed reconstruction with tissue expanders after custom bolus PMRT.

Our 2 cohorts were separated chronologically: standard bolus was used earlier in the 10-year study period and custom bolus was used later. This creates potential confounders and limits our ability to draw definitive conclusions. For instance, surgical technique may be improved over time, which may result in fewer complications. Additionally, more free flaps were performed later in the study period. These are better vascularized than pedicled flaps, and have less fat necrosis. Conversely, emphasizing the importance of clinical exam, documentation, and follow-up has led to increased detection and documentation of complications. The chronological separation may also benefit the study design in that the clear division in PMRT technique removes procedural selection bias, similar to what occurs in studies that compare types of autologous tissue reconstruction.[43]

Plastic surgeons and radiation oncologists must balance the concerns regarding technical delivery and long-term toxicities of PMRT in the setting of immediate breast reconstruction[27] with the prolonged patient discomfort in delayed reconstruction after PMRT. Radiation causes inflammatory changes to the microvasculature, causes microthrombi, and leads to vessel occlusion and atherosclerosis.[45] Custom bolus has the potential to assuage these concerns. Additionally, this technique adapts with our changing surgical practice, as many centers now perform total skin-sparing or nipple-sparing mastectomies. Radiation boost fields should target the chest wall, the area of highest risk of recurrence, and away from the skin and mastectomy scar.[11] Although our cohorts are small, we have 5-year follow-up data showing no difference in local or distant cancer recurrence rates between the 2 techniques. Custom bolus allows the radiation oncologist to tailor skin and scar radiation exposure while providing adequate dosage to the tissues at risk, thus not compromising oncologic safety. This offers improved nipple/areola complex survival and aesthetics. The use of custom bolus can be achieved by any institution, and there are a variety of ways it may be performed, with our description just 1 option. Another option is to use brass mesh bolus, which also conforms to the shape of the reconstruction.[46]

We propose that plastic surgeons advocate for custom bolus as their preferred method of PMRT because this method has promising preliminary results on patient outcomes and would facilitate greater collaboration between specialties. Custom bolus is easily fabricated, cost-effective, and placement is straightforward and reproducible. The improved dose homogeneity created with the individualized, customized contoured surface bolus is hypothesized to account for improved aesthetic outcomes.[28] This technique allows the radiation oncologist to recognize, plan, and avoid the mammary vessels and anastomoses with radiation beams. Additionally, by avoidance of radiation to the skin, scar, and internal mammary nodes, reconstruction complications are minimized.[28] Although custom bolus requires time investment from both the plastic surgery and radiation oncology teams, and institutional support for the added costs and infrastructure (designing molds, software for delivery, and employing a physicist), we believe its potential for superior outcomes are worth the investment.

Prospective research is under way at our institution to provide objective means of recording postoperative outcomes and complications to better understand the relationship between immediate autologous breast reconstruction and custom bolus PMRT. We are considering tissue sampling, as well as noninvasive imaging, as a way to quantify outcomes with this technique. Additionally, we are incorporating BREAST-Q as part of every breast cancer patient's follow-up to document patient reported outcomes. Furthermore, we are working with the radiation oncology department to establish guidelines for a more uniform approach to postautologous reconstruction radiation therapy.

CONCLUSIONS

Custom bolus radiation therapy offers individualized PMRT that can tailor radiation to the skin, incision, and vascular pedicle in autologous tissue breast reconstruction. In our patients, custom bolus resulted in fewer skin changes and decreased volume loss. With larger patient populations and better standardization of outcomes reporting, we anticipate more support for this novel method.

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