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Mastectomy Weight and Tissue Expander Volume Predict Necrosis and Increased Costs Associated with Breast Reconstruction

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Introduction: Impaired vascular perfusion in tissue expander (TE) breast reconstruction leads to mastectomy skin necrosis. We investigated factors and costs associated with skin necrosis in postmastectomy breast reconstruction.
Methods: Retrospective review of 169 women with immediate TE placement following mastectomy between May 1, 2009 and May 31, 2013 was performed. Patient demographics, comorbidities, intraoperative, and postoperative outcomes were collected. Logistic regression analysis on individual variables was performed to determine the effects of tissue expander fill volume and mastectomy specimen weight on skin necrosis. Billing data was obtained to determine the financial burden associated with necrosis.
Results: This study included 253 breast reconstructions with immediate TE placement from 169 women. Skin necrosis occurred in 20 flaps for 15 patients (8.9%). Patients with hypertension had 8 times higher odds of skin necrosis [odd ratio (OR), 8.10, $P < 0.001$]. Patients with TE intraoperative fill volumes >300 cm^3 had 10 times higher odds of skin necrosis (OR, 10.66, $P = 0.010$). Volumes >400 cm^3 had 15 times higher odds of skin necrosis (OR, 15.56, $P = 0.002$). Mastectomy specimen weight was correlated with skin necrosis. Specimens >500 g had 10 times higher odds of necrosis and specimens >1000 g had 18 times higher odds of necrosis (OR, 10.03 and OR, 18.43; $P = 0.003$ and $P < 0.001$, respectively). Mastectomy skin necrosis was associated with a 50% increased inpatient charge.
Conclusion: Mastectomy flap necrosis is associated with HTN, larger TE volumes and mastectomy specimen weights, resulting in increased inpatient charges. Conservative TE volumes should be considered for patients with hypertension and larger mastectomy specimens. *(Plast Reconstr Surg Glob Open 2015;3:e450; doi: 10.1097/GOX.0000000000000408; Published online 14 July 2015.)*

Staged breast reconstruction with immediate tissue expander (TE) placement following mastectomy offers advantages, making it strongly favored over delayed reconstruction at many institutions.[1–3] Staging allows patients to contemplate breast reconstruction options, and placement of a TE does not preclude the patient from the final reconstruction of their choosing. Additionally, timed expansions permit gradual stretching of the breast pocket and skin envelope. The reconstructive surgeon is provided with a larger breast pocket for the eventual implant or autologous transfer, resulting in better aesthetic outcomes.[4–6] Staged breast reconstruction with TE placement can provide all of

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the above without interrupting oncologic therapy. TEs do not interfere with delivery or efficacy of adjuvant chemotherapy, although there is conflict in the literature in regard to cosmesis and timing of TE placement or expansion with chest wall radiation.[7–19]

Although immediate TE placement following mastectomy is a desirable option for many patients, the procedure is not without risk. Complications include implant failure and rupture, fat necrosis, skin necrosis, and infection.[4,16,20–22] Causes of impaired vascular perfusion via the microcirculation can lead to inadequate oxygenation of the overlying skin flap.[23–26] Microcirculation is impaired with comorbidities such as smoking, hypertension, hyperlipidemia, and obesity.[27,28] Impaired oxygenation can lead to mastectomy skin necrosis acutely.[4,16,20]

Severe mastectomy skin necrosis can lead to infection, reoperation, and implant removal. Necrosis-associated complications can result in emotional distress and additional financial costs to a patient already facing the psychological and physical stress associated with breast cancer.

The incidence of mastectomy skin necrosis varies in the literature between 10% and 40%.[26,29–32] Although the precise etiology underlying mastectomy skin necrosis as it relates to mastectomy specimen weight and intraoperative TE fill volume remains disputed, we hypothesized that increased mastectomy specimen weights and larger intraoperative TE fill volumes would correlate with wound healing complications.[33–37] We also hypothesized that patients with known surgical comorbidities would have higher rates of wound healing complications. In a retrospective review, this study investigated factors associated with mastectomy skin necrosis in breast reconstruction and its associated costs.

PATIENTS AND METHODS

This study was approved by the Johns Hopkins Medicine Institutional Review Board, and a representative sample of patients having TE placement following mastectomy at Johns Hopkins Hospital between May 1, 2009, and May 31, 2013, were retrospectively reviewed. Patients who met the following inclusion criteria were included: (1) having bilateral or unilateral postmastectomy TE placement, (2) receipt of a simple total, modified radical, or nipple-sparing mastectomy, (3) any history of adjuvant chemotherapy or radiotherapy. Patients were excluded if: (1) the TE was not immediately placed postmastectomy, (2) they were <30 days postoperative at the time of this review, (3) the breast specimen weights and/or intraoperative TE fill volumes were not recorded, or (4) they were lost to follow-up.

All clinic, operative, and emergency room notes were reviewed. Patient demographics and comorbidities were documented. We recorded intraoperative parameters including mastectomy specimen weight and the initial intraoperative TE fill volume. We considered small mastectomy specimens as ≤500 g and large specimens as those weighing >500 g. Divisions were also made to account for extremely large mastectomy specimens, which we considered as any specimen >1000 g. We considered a conservative intraoperative fill as ≤300 cm^3 while large fills were considered anything >300 cm^3 to ≤400 cm^3. Very large intraoperative fills were those >400 cm^3.

Postoperative outcomes included major complications of mastectomy flap necrosis, reoperation, debridement, removal of the implant, or hospital readmission for infection management. Minor complications included infection requiring outpatient antibiotics, seroma, or hematoma. Our primary outcome of interest was mastectomy flap necrosis, which we defined as full-thickness tissue loss leading to eschar formation, and was documented by nurse practitioners in the Johns Hopkins Breast Center. Treatment was documented for patients who developed necrosis. Aggressive treatment included reoperation and debridement with implant removal. Conservative treatment included topical Silvadene (Pfizer, New York, N.Y.), local excision in office, or oral antibiotics.

Billing data were obtained for all women to determine the additional financial burden associated with necrosis. Patients who developed necrosis requiring reoperation, debridement, and implant removal were matched to 1–2 control patients in the same sample who did not develop necrosis by self-reported race, age ± 5 years, surgery within one calendar year, type of mastectomy, body mass index (BMI) category (or weight within a 15-pound range if BMI was unavailable), smoking status, and hypertension status. For both case and control patients, total operating room and inpatient stay charges were combined and averaged for all stays within 30 days of TE placement.

Statistical Analysis

All data were managed using REDCap software[38] (Version 4.13.1—©2012 Vanderbilt University,

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Nashville, Tenn.). Statistical analysis was performed in Stata, Version 11.0 (StataCorp, College Station, Tex.). Statistical analysis was performed per patient as well as per breast. Frequencies were calculated for categorical and binary variables, and means and SDs are provided for continuous variables. Fisher's exact test was used to compare binary and categorical data between patients with and without mastectomy skin necrosis, whereas Wilcoxon rank-sum test was used for the same analysis among continuous variables. Logistic regression analysis on individual variables for each outcome was performed. For breast-dependent outcomes, standard errors were adjusted for within-patient correlation for bilateral operations using clustering within simple logistic regressions. Odds ratios (ORs) were calculated using simple logistic regressions and reported with a 95% confidence interval. Multivariable logistic regression was used to explore the relationship between mastectomy specimen weight and intraoperative TE fill volume in an effort to isolate the variables as potential cofounders for mastectomy skin necrosis.

Surgical Technique

A dedicated breast surgeon performed all mastectomies. Mastectomy specimens were weighed by nurses and recorded by the attending reconstructive surgeon before TE placement. All TEs were placed subpectoral and filled as described in the literature.[39] The use of acellular dermal matrix (ADM) was recorded. Not all TEs were filled at the time of placement. For TEs that were filled, the intraoperative volumes were determined by the clinical judgment of the attending reconstructive surgeon. Perfusion after placement and filling of the TE was also determined by clinical assessment of the attending reconstructive surgeon.

RESULTS

This study included 253 staged breast reconstructions with immediate TE placement from 169 women (bilateral reconstruction, $n = 84$; unilateral reconstruction, $n = 85$). Patient demographics and comorbidities are documented in Table 1. Intraoperative parameters and postoperative outcomes are documented in Tables 2 and 3. Median inpatient

Table 1. Patient Demographics

	Population ($n = 169$)	+ Skin Necrosis ($n = 15$)	– Skin Necrosis ($n = 154$)	*P*-value	Odds Ratio
White	133 (79%)	12 (7%)	121 (72%)	0.992	1.00
African American	22 (13%)	2 (1%)	20 (12%)	0.837	1.01
Other race	14 (8%)	1 (1%)	13 (8%)	0.814	0.77
BMI	25.7±6.0	30.6±5.9	25.2±5.7	**0.006**	**2.55**
Diabetes	7 (4.1%)	0 (0.0%)	7 (4.5%)	—	—
Hypertension	25 (14.7%)	7 (43.7%)	18 (11.6%)	**<0.001**	**8.10**
Age at surgery	48.4±10.7	55.4±10.2	47.7±10.5	—	—
Former or current smoker	40 (23.6%)	6 (40.0%)	34 (22.0%)	0.458	1.61
Bilateral procedure	84 (49.7%)	8 (53.3%)	78 (50.6%)	0.952	0.97

Race, age, BMI, and preoperative comorbidities were recorded for all 169 patients in the sample. Demographics and comorbidities were analyzed on a per-patient basis. Percentages are given based on the total number of patients in the sample. Patients with hypertension had an 8 times higher odds of developing skin necrosis compared with those who did not. BMI was correlated with skin necrosis for patients with a BMI > 30. There was no association between smoking status and skin necrosis in our sample.

Table 2. Breasts with Skin Necrosis

Values Given for 253 Total Breasts	Total Cases	+ Skin Necrosis	*P*-value	Odds Ratio
Breast TE fill volume initial				
≤300 cm^3	215	11 (4%)	0.704	1.55
>300 cm^3 ≤400 cm^3	26	6 (2%)	**0.010**	**10.66**
>400 cm^3	12	3 (1%)	**0.002**	**15.56**
Breast specimen weight				
≤500 g	131	2 (1%)	**0.002**	**0.09**
>500 g ≤1000 g	104	14 (6%)	**0.003**	**10.03**
>1000 g	18	4 (2%)	**<0.001**	**18.43**

The influence of tissue expander intraoperative fill volume and mastectomy specimen weight on the development of skin necrosis was analyzed on a per-breast basis, with clustering to account for within-patient correlation. The initial volume of saline injected into the tissue expander after it was placed and the postmastectomy breast specimen weight were recorded for each breast. These values were subsequently divided into categories. The total number of breasts within each category is listed as well as the number of breasts in each category that developed necrosis. Percentages are given over total number of breasts. Larger tissue expander fill volumes and larger mastectomy specimen weights were associated with significantly higher odds of mastectomy skin necrosis.

Table 3. Per Patient Mastectomy Characteristics

	Population (n = 169)	+ Skin Necrosis (n = 15)	– Skin Necrosis (n = 154)
Mean/SD specimen weight	535 ± 316	846 ± 420	504 ± 288
Median specimen weight	478	750	452
Specimen weight range	54–2040	390–2040	54–1555
Mean/SD fill volume	208 ± 121	313 ± 125	198 ± 116
Median fill volume	200	300	200
Fill volume range	0–500	50–500	0–500

Weights are expressed in grams and volumes in cm^3. Means, medians, SDs, and ranges for mastectomy specimen weights and the initial tissue expander fill volumes are expressed on a per-patient basis. For patients with bilateral procedures, breast specimen weights and tissue expander fill volumes were averaged. Patients with mastectomy skin necrosis had higher median flap weights and larger median tissue expander fill volumes.

stay was 1 day (range, 1–2 days). Skin necrosis occurred in 20 skin flaps for 15 patients (8.9%). Two cases of necrosis occurred in African American patients (1%), 1 case in a patient of undisclosed race (1%), and the remaining 12 patients were white (7%). Mean time to documentation of skin necrosis was 17.6 days (range, 5–36 days). Weights of all mastectomy flaps and volumes for all intraoperative TE fills are described in Tables 3 and 4.

Data were first analyzed on a per-patient basis. Patients with a previous diagnosis of hypertension had 8 times the odds of developing skin necrosis compared with patients without hypertension (OR, 8.10; $P < 0.001$; Table 1). BMI was found to be proportional to both increasing TE fill volumes and larger mastectomy specimen weights. However, BMI was not correlated with necrosis until patients reached a BMI > 30 ($P = 0.0034$). Patients with and without necrosis were comparable in relation to other causes of surgical comorbidities, age, race, and proportion of bilateral procedures. Ninety-six percent ($n = 242$) of breasts were reconstructed with ADM. Breasts reconstructed with ($n = 242$) or without ($n = 11$) ADM had no significant difference in rates of necrosis or other complications.

To elucidate the relationship between TE fill volumes, mastectomy specimen weights, and skin necrosis, our data were reanalyzed per breast with clustering to account for within-patient bias. When adjusted for hypertension status, mastectomy skin flaps receiving large TE fill volumes were found to have significantly higher rates of mastectomy skin necrosis. Intraoperative TE fill volumes ranged from 0 to 500 cm^3 (mean = 201 cm^3). There were 215 breasts with intraoperative fills ≤300 cm^3, 26 breasts >300 cm^3 to ≤400 cm^3, and 12 breasts >400 cm^3 (Table 2). Eleven of the 215 TEs filled up to 300 cm^3 developed mastectomy necrosis; however, this was not statistically significant (OR, 1.55; $P = 0.704$). Mastectomy skin flaps receiving intraoperative TE fills >300 cm^3 to ≤400 cm^3 had 10 times greater odds of developing necrosis when compared with conservative fill volumes (OR, 10.66; $P = 0.010$). Once intraoperative TE fill volumes reached >400 cm^3, mastectomy skin flaps had 15 times greater odds of developing necrosis (OR, 15.56; $P = 0.002$). No patients in our study developed mastectomy skin necrosis if their TE was placed and remained unfilled ($n = 13$; Tables 3 and 4).

Mastectomy specimen weights were recorded from 54 to 2040 g (mean = 522g). As described in Table 2, there were 131 cases of specimens weighing ≤500 g; only 2 of those flaps developed necrosis (1.5%). Mastectomy specimens weighing >500 to ≤1000 g ($n = 104$) had 10 times higher odds of developing skin necrosis when compared with smaller specimens, and specimens weighing >1000 g ($n = 18$) were found to have 18 times higher odds of developing skin necrosis compared with smaller specimen weights (OR, 10.03; $P = 0.003$ and OR, 18.43; $P < 0.001$, respectively).

Analysis showed that patients with skin necrosis were at increased risk for other surgical morbidities. Patients developing necrosis had 15 times higher

Table 4. Per Breast Mastectomy Characteristics

	Population (n = 253)	+ Skin Necrosis (n = 20)	– Skin Necrosis (n = 233)
Mean/SD specimen weight	522 ± 301	814 ± 387	497 ± 280
Median specimen weight	474	749	450
Specimen weight range	54–2040	300–2040	54–1555
Mean/SD fill volume	201 ± 119	315 ± 115	191 ± 115
Median fill volume	200	300	200
Fill volume range	0–500	50–500	0–500

Weights are expressed in grams and volumes in cm^3. Means, medians, SDs, and ranges for mastectomy specimen weights and the initial tissue expander fill volumes are expressed on a per-breast basis. Breasts with skin necrosis had larger median mastectomy specimen weights and larger median tissue expander fill volumes.

Table 5. Postoperative Outcomes

	Population (n = 169)	+ Skin Necrosis (n = 15)	P	Odds Ratio
Infection	15	15 (9%)	**<0.001**	**15.12**
Intravenous antibiotics	10	10 (6%)	—	—
Oral antibiotics	15	15 (9%)	—	—
Topical cream (Silvadene)	2	2 (1%)	—	—
Readmission	10	10 (6%)	—	—
Reoperation	10	10 (6%)	—	—
Debridement	10	10 (6%)	—	—
TE removal	10	10 (6%)	**<0.001**	**15.83**
Seroma	11	11 (6%)	—	—
Hematoma	3	3 (2%)	—	—

Postoperative outcomes data were recorded for all patients and are shown for patients with mastectomy skin necrosis. Adverse outcomes were only identified in patients who developed mastectomy skin necrosis. Once identified, mastectomy skin necrosis was treated with antibiotics, Silvadene, and/or reoperation, debridement, and removal. Patients with mastectomy skin necrosis had a 15 times higher odds of developing an infection requiring intervention and an almost 16 times higher odds of requiring their tissue expander to be prematurely removed (OR, 15.12 and 15.83; $P < 0.001$ for both).

odds of developing a postoperative infection (OR, 15.12; $P < 0.001$) and almost 16 times higher odds of requiring their TE to be prematurely removed (OR, 15.83; $P < 0.001$). Of the 15 patients with necrosis, 10 required readmission with intravenous antibiotics and reoperation with surgical debridement and removal of their TE (67%). All 15 patients who developed necrosis were treated with oral antibiotics. Of the 5 patients who did not require a reoperation, 2 were given a course of topical Silvadene cream and 1 had their necrosis locally excised in office. The remaining 2 patients were resolved of their mastectomy skin necrosis with oral antibiotics alone (Table 5).

Table 6. Cost of Inpatient Stay

With Necrosis and Debridement		Matched Controls	
Patient	Necrosis Cost (USD)	Patient	No Necrosis Cost (USD)
		Control 1	26,500
Case 1	31,735	Control 2	7,983
Case 2	52,512	Control 3	28,342
		—	—
Case 3	46,001	Control 4	23,096
		Control 5	27,632
Case 4	28,460	Control 6	28,180
		—	—
Case 5	22,011	Control 7	17,184
		Control 8	18,723
Case 6	33,928	Control 9	21,929
		—	—
Case 7	34,146	Control 10	18,587
		Control 11	20,126
Case 8	26,815	Control 12	27,632
		Control 13	31,735
Case 9	24,640	Control 14	12,399
		—	—
Case 10	30,885	Control 15	20,517
		—	—
Average	33,113	—	22,038
Difference between patients with and without necrosis			$11,076

The total inpatient and operating room charges for each patient who developed mastectomy skin necrosis were obtained, and the combined charges for all of the patients with mastectomy skin necrosis were averaged. Each patient was matched to 1 or 2 control patients based on self-identified race, smoking status, hypertension status, age, BMI category, bilateral procedure, tissue expander fill volume category, and mastectomy specimen weight category. If 2 control patients were available per case patient, the 2 control patients' charges were combined and averaged. Patients who developed mastectomy skin necrosis were charged $11,076 more on average, which is a 50% increase in cost.

A charge comparison was performed to determine the difference in inpatient charges between patients who developed necrosis requiring reoperation, debridement, and removal of the TE with those who did not. Of the 15 patients who developed mastectomy skin necrosis, 10 required this surgical intervention. These patients were matched to 1–2 patients in the same sample who did not develop necrosis based on the following criteria: self-identified race, smoking status, hypertension status, BMI within the same standard clinical category (or weight within a 15-pound range if BMI was unavailable), age within a 10-year range, bilateral procedure, TE fill volume, and mastectomy specimen weight in categories as described above. If 2 control patients were available for a given case patient, their inpatient charges were combined and averaged. As described in Table 4, patients with necrosis requiring surgical debridement and intravenous antibiotics within 30 days of their TE being placed suffered an average inpatient charge of $33,113 compared with a $22,038 average inpatient charge to the control patients. This is a 50% increase (mean = $11,845) in inpatient charges for patients requiring surgical intervention for skin necrosis (Table 6).

DISCUSSION

Immediate TE placement in staged breast reconstruction is often preferred to improve cosmesis and patient satisfaction.[1,16,40] Postmastectomy TE placement allows patients to receive adjuvant chemotherapy as needed.[9,12,13] Because expansions can

often be continued during this time, immediate TE placement is also highly efficient; it contributes to improving patient quality of life by allowing patients to more quickly move beyond the emotional distress associated with a breast cancer diagnosis and treatment.[41,42]

Although the type of mastectomy required for oncologic treatment and the margin of breast tissue removed are dictated by TNM Classification of Malignant Tumors and clinical assessment, the amount of saline initially injected into the TE after it is placed is at the discretion of the attending reconstructive surgeon.[43,44] Often this decision is dictated by a combination of patient request or concern about aesthetic outcome, the reconstructive surgeon's concerns with temporary aesthetic outcome, and/or the reconstructive surgeon's ability to approximate the edges of the skin envelope without compromising vascular perfusion and venous drainage.[45,46]

We demonstrated that when larger mastectomy specimens are removed for oncologic purposes, there are significantly higher odds of skin necrosis. We also illustrated that larger intraoperative TE fill volumes are associated with mastectomy skin necrosis. Of note, 100% of the TEs placed without fills were without necrosis 30 days postoperatively. One may presume that removing larger mastectomy specimens leaves larger mastectomy skin flaps that require larger TE volumes; however, that is not always the case based on each patient's individual body habitus and their mastectomy needs for oncologic purposes. As the relationship between these parameters has not been fully elucidated in the literature, our study found the effects of the mastectomy specimen weight and TE fill volume on mastectomy skin necrosis to be independent of one another. We hypothesized that BMI may be a common factor between the two; however, in our study, BMI only increased the probability of developing mastectomy skin necrosis and the relationship is only significant for patients with BMIs > 30 ($P = 0.0034$).

Thus, postmastectomy TEs must be filled to optimize aesthetic outcomes and ensure the viability of the remaining mastectomy skin flap. Several studies have shown surgical outcomes to be dependent on operator experience.[47–52] Although questions have been raised about operator use, quality of the mastectomy skin flaps, and surgical outcomes in breast reconstruction, our study found no association between skin necrosis and the type of mastectomy performed or between necrosis and the attending surgical oncologist or reconstructive surgeon placing and filling the TE (data not shown). Further, there was no association between placement of acellular dermal matrix and necrosis.

Historically, the literature has been mixed as to whether neoadjuvant chemotherapy or a history of chest wall radiation increases the odds of wound healing complications.[13,15,17,26,53,54] Our sample showed no association between skin necrosis and a patient's history of chemotherapy or radiation, confirming studies that have shown staged breast reconstruction with TE placement to be not contraindicated with oncologic therapy (data not shown).

Hypertension has long been a predictor of wound healing complications.[27,29,55–58] Our study was able to demonstrate that patients with hypertension had 8 times higher odds of developing necrosis. Race has previously been documented to be associated with fat necrosis in staged breast reconstruction due to difficulty in clinically evaluating perfusion.[24] In our study, race demonstrated no statistically significant association with skin necrosis. Similarly, other known causes of surgical morbidity, including smoking and diabetes mellitus, showed no statistically significant association with mastectomy skin necrosis.[30,55,56,59–61] We hypothesize that these associations cannot be confirmed due to our small sample size of patients who developed necrosis and were smokers, the small number of African American, Asian, and Hispanic women in our study, and a lack of patients developing necrosis who were diabetic.

We found mastectomy skin necrosis to lead to 15 times higher odds of postoperative infection, 16 times higher odds of reoperation, and a 50% increase in inpatient charges. As receiving a breast cancer diagnosis, undergoing oncologic treatment, and consenting for breast reconstruction are documented to cause significant psychological challenges, emotional trauma, and lead to posttraumatic stress disorder in some patients, further complications from mastectomy skin necrosis likely have a negative psychosocial impact and should be mitigated where possible.[42,62–65] Further, with reimbursements threatened and increased pressure on surgeons and hospitals to reduce readmissions from surgical site infections under the Affordable Care Act, clinicians should be cognizant of these additional complications, their associated costs, and ways to prevent them.[66–68]

The strengths of this study include the ability to provide clear clinical parameters for intraoperative TE filling in patients with larger mastectomy specimens, larger BMIs, and known surgical comorbidities. Patients with hypertension, BMIs >30, and/or mastectomy specimens weighing >500 g should be considered for more conservative TE fill volumes of $<300\ cm^3$ to mitigate mastectomy skin necrosis. The main limitations of this study include a retrospective study design, the small number of African American women in our study population ($n = 22$, with only 1%

of those women developing skin necrosis), and a low incidence rate of necrosis (8.9%). We hypothesize that these limited our ability to uncover correlates between BMI and other known surgical morbidities that could likely be described by a larger sample size.

CONCLUSIONS

Breast reconstruction with TE placement is a viable breast reconstruction option. However, as with any surgical intervention, placement of a TE is not without some surgical morbidity. Wound healing complications from impaired vascular perfusion can lead to mastectomy skin necrosis, infection, and implant failure. Our study found hypertension to be associated with mastectomy skin necrosis. BMIs >30 were associated with increased probability of developing skin necrosis. Patients receiving intraoperative TE fill volumes >300 cm^3 and patients with mastectomy specimens weighing >500 g have significantly higher odds of developing necrosis. Additionally, patients with necrosis suffered significantly higher odds of developing a postoperative infection and requiring reoperation with surgical debridement to remove the TE. These additional surgical interventions were associated with 50% higher inpatient charges. As such, conservative intraoperative TE fill volumes <300 cm^3 should be considered for patients with known surgical comorbidities, larger BMIs, and mastectomy specimens weighing >500 g. Reoperation due to mastectomy skin necrosis poses a significant financial and emotional burden to the patient with breast cancer that can potentially be avoided with guided clinical judgment. Improved surgical outcomes, patient quality of life, along with reduction in financial burdens can be obtained using these parameters as guidelines in staged breast reconstruction with immediate TE placement.

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REFERENCES

1. Manahan MA, Prucz RB, Shridharani SM, et al. Long-term follow-up of changing practice patterns in breast reconstruction due to increased use of tissue expanders and perforator flaps. *Microsurgery* 2014;34:595–601.
2. Morrow M, Scott SK, Menck HR, et al. Factors influencing the use of breast reconstruction postmastectomy: a National Cancer Database study. *J Am Coll Surg.* 2001;192:1–8.
3. American Society of Plastic Surgeons. 2007 Plastic Surgery Procedural Statistics: Reconstructive Breast Surgery. Available at: http://www.plasticsurgery.org. Accessed March 27, 2014.
4. Cunha MS, Nakamoto HA, Herson MR, et al. Tissue expander complications in plastic surgery: a 10-year experience. *Rev Hosp Clin Fac Med Sao Paulo* 2002;57:93–97.
5. Spear SL, Boehmler J. Immediate two-stage breast reconstruction utilizing a tissue expander and implant. In: Spear SL, ed. *Surgery of the Breast: Principles and Art.* Philadelphia, Pa.: Lippincott, Williams and Wilkins; 2006:463.
6. Beasley ME. Delayed two-stage expander/implant reconstruction. In: Spear SL, ed. *Surgery of the Breast: Principles and Art.* Philadelphia, Pa.: Lippincott, Williams and Wilkins; 2006:489.
7. Rosson GD, Magarakis M, Shridharani SM, et al. A review of the surgical management of breast cancer: plastic reconstructive techniques and timing implications. *Ann Surg Oncol.* 2010;17:1890–1900.
8. Warren Peled A, Itakura K, Foster RD, et al. Impact of chemotherapy on postoperative complications after mastectomy and immediate breast reconstruction. *Arch Surg.* 2010;145:880–885.
9. Mitchem J, Herrmann D, Margenthaler JA, et al. Impact of neoadjuvant chemotherapy on rate of tissue expander/implant loss and progression to successful breast reconstruction following mastectomy. *Am J Surg.* 2008;196:519–522.
10. Tallet AV, Salem N, Moutardier V, et al. Radiotherapy and immediate two-stage breast reconstruction with a tissue expander and implant: complications and esthetic results. *Int J Radiat Oncol Biol Phys.* 2003;57:136–142.
11. Cordeiro PG, Pusic AL, Disa JJ, et al. Irradiation after immediate tissue expander/implant breast reconstruction: outcomes, complications, aesthetic results, and satisfaction among 156 patients. *Plast Reconstr Surg.* 2004;113:877–881.
12. Nahabedian MY, Momen B. The impact of breast reconstruction on the oncologic efficacy of radiation therapy: a retrospective analysis. *Ann Plast Surg.* 2008;60:244–250.
13. Wright JL, Cordeiro PG, Ben-Porat L, et al. Mastectomy with immediate expander-implant reconstruction, adjuvant chemotherapy, and radiation for stage II-III breast cancer: treatment intervals and clinical outcomes. *Int J Radiat Oncol Biol Phys.* 2008;70:43–50.
14. Classen J, Nitzsche S, Wallwiener D, et al. Fibrotic changes after postmastectomy radiotherapy and reconstructive surgery in breast cancer. A retrospective analysis in 109 patients. *Strahlenther Onkol.* 2010;186:630–636.
15. Chawla AK, Kachnic LA, Taghian AG, et al. Radiotherapy and breast reconstruction: complications and cosmesis with TRAM versus tissue expander/implant. *Int J Radiat Oncol Biol Phys.* 2002;54:520–526.
16. Krueger EA, Wilkins EG, Strawderman M, et al. Complications and patient satisfaction following expander/implant breast reconstruction with and without radiotherapy. *Int J Radiat Oncol Biol Phys.* 2001;49:713–721.
17. Caffo O, Cazzolli D, Scalet A, et al. Concurrent adjuvant chemotherapy and immediate breast reconstruction with skin expanders after mastectomy for breast cancer. *Breast Cancer Res Treat.* 2000;60:267–275.
18. Gouy S, Rouzier R, Missana MC, et al. Immediate reconstruction after neoadjuvant chemotherapy: effect on adjuvant treatment starting and survival. *Ann Surg Oncol.* 2005;12:161–166.
19. Giacalone PL, Rathat G, Daures JP, et al. New concept for immediate breast reconstruction for invasive cancers: feasibility, oncological safety and esthetic outcome of post-neoadjuvant therapy immediate breast reconstruction

versus delayed breast reconstruction: a prospective pilot study. *Breast Cancer Res Treat.* 2010;122:439–451.
20. Sbitany H, Sandeen SN, Amalfi AN, et al. Acellular dermis-assisted prosthetic breast reconstruction versus complete submuscular coverage: a head-to-head comparison of outcomes. *Plast Reconstr Surg.* 2009;124:1735–1740.
21. Nahabedian MY, Tsangaris T, Momen B, et al. Infectious complications following breast reconstruction with expanders and implants. *Plast Reconstr Surg.* 2003;112:467–476.
22. Sullivan SR, Fletcher DR, Isom CD, et al. True incidence of all complications following immediate and delayed breast reconstruction. *Plast Reconstr Surg.* 2008;122:19–28.
23. Chun YS, Verma K, Rosen H, et al. Use of tumescent mastectomy technique as a risk factor for native breast skin flap necrosis following immediate breast reconstruction. *Am J Surg.* 2011;201:160–165.
24. Mulvey CL, Cooney CM, Daily FF, et al. Increased flap weight and decreased perforator number predict fat necrosis in DIEP breast reconstruction. *Plast Reconstr Surg Glob Open* 2013;1:1–7.
25. Rao R, Saint-Cyr M, Ma AM, et al. Prediction of post-operative necrosis after mastectomy: a pilot study utilizing optical diffusion imaging spectroscopy. *World J Surg Oncol.* 2009;7:91.
26. Carlson GW, Bostwick J III, Styblo TM, et al. Skin-sparing mastectomy. Oncologic and reconstructive considerations. *Ann Surg.* 1997;225:570–578.
27. Levy BI, Schiffrin EL, Mourad JJ, et al. Impaired tissue perfusion: a pathology common to hypertension, obesity, and diabetes mellitus. *Circulation* 2008;118:968–976.
28. Wiernsperger N, Nivoit P, De Aguiar LG, et al. Microcirculation and the metabolic syndrome. *Microcirculation* 2007;14:403–438.
29. Algaithy ZK, Petit JY, Lohsiriwat V, et al. Nipple sparing mastectomy: can we predict the factors predisposing to necrosis? *Eur J Surg Oncol.* 2012;38:125–129.
30. Chang DW, Reece GP, Wang B, et al. Effect of smoking on complications in patients undergoing free TRAM flap breast reconstruction. *Plast Reconstr Surg.* 2000;105: 2374–2380.
31. Phillips BT, Lanier ST, Conkling N, et al. Intraoperative perfusion techniques can accurately predict mastectomy skin flap necrosis in breast reconstruction: results of a prospective trial. *Plast Reconstr Surg.* 2012;129:778e–788e.
32. Gurtner GC, Timek E. Decreasing Complications in Immediate Breast Reconstruction. Surgeon Reports. Available at: http://novadaq.com/node/494. Accessed March 29, 2014.
33. Chirappapha P, Petit JY, Rietjens M, et al. Nipple sparing mastectomy: does breast morphological factor related to necrotic complications? *Plast Reconstr Surg Glob Open* 2014;2:e99.
34. Duggal CS, Grudziak J, Metcalfe DB, et al. The effects of breast size in unilateral postmastectomy breast reconstruction. *Ann Plast Surg.* 2013;70:506–512.
35. Tanna N, Broer PN, Weichman KE, et al. Microsurgical breast reconstruction for nipple-sparing mastectomy. *Plast Reconstr Surg.* 2013;131:139e–147e.
36. Khavanin N, Jordan S, Lovecchio F, et al. Synergistic interactions with a high intraoperative expander fill volume increase the risk for mastectomy flap necrosis. *J Breast Cancer* 2013;16:426–431.
37. Munhoz AM, Aldrighi CM, Montag E, et al. Clinical outcomes following nipple-areola-sparing mastectomy with immediate implant-based breast reconstruction: a 12-year experience with an analysis of patient and breast-related factors for complications. *Breast Cancer Res Treat.* 2013;140:545–555.
38. Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform.* 2009;42:377–381.
39. Rawlani V, Buck DW II, Johnson SA, et al. Tissue expander breast reconstruction using prehydrated human acellular dermis. *Ann Plast Surg.* 2011;66:593–597.
40. Kronowitz SJ, Hunt KK, Kuerer HM, et al. Delayed-immediate breast reconstruction. *Plast Reconstr Surg.* 2004;113:1617–1628.
41. Stevens LA, McGrath MH, Druss RG, et al. The psychological impact of immediate breast reconstruction for women with early breast cancer. *Plast Reconstr Surg.* 1984;73:619–628.
42. Al-Ghazal SK, Fallowfield L, Blamey RW. Comparison of psychological aspects and patient satisfaction following breast conserving surgery, simple mastectomy and breast reconstruction. *Eur J Cancer* 2000;36:1938–1943.
43. Radovan C. Breast reconstruction after mastectomy using the temporary expander. *Plast Reconstr Surg.* 1982;69:195–208.
44. Kwong A, Sabel S, Chagpar AB. Mastectomy: Indications, Types, and Concurrent Axillary Lymph Node Management. Waltham, Mass.: UpToDate. Available at: http://www.uptodate.com. Accessed March 25, 2014.
45. Haddock N, Levine J. Breast reconstruction with implants, tissue expanders and AlloDerm: predicting volume and maximizing the skin envelope in skin sparing mastectomies. *Breast J.* 2010;16:14–19.
46. Nahabedian M, Chagpar AB, Duda RB. Breast Reconstruction in Women With Breast Cancer. Waltham, Mass.: UpToDate. Available at: http://www.uptodate.com. Accessed March 26, 2014.
47. Antony AK, Chen WF, Kolokythas A, et al. Use of virtual surgery and stereolithography-guided osteotomy for mandibular reconstruction with the free fibula. *Plast Reconstr Surg.* 2011;128:1080–1084.
48. Hammond JW, Queale WS, Kim TK, et al. Surgeon experience and clinical and economic outcomes for shoulder arthroplasty. *J Bone Joint Surg Am.* 2003;85A:2318–2324.
49. Schmidt CM, Turrini O, Parikh P, et al. Effect of hospital volume, surgeon experience, and surgeon volume on patient outcomes after pancreaticoduodenectomy: a single-institution experience. *Arch Surg.* 2010;145:634–640.
50. Duclos A, Peix JL, Colin C, et al; CATHY Study Group. Influence of experience on performance of individual surgeons in thyroid surgery: prospective cross sectional multicentre study. *BMJ* 2012;344:d8041.
51. Vickers AJ, Bianco FJ, Serio AM, et al. The surgical learning curve for prostate cancer control after radical prostatectomy. *J Natl Cancer Inst.* 2007;99:1171–1177.
52. Broeders JA, Draaisma WA, Rijnhart-de Jong HG, et al. Impact of surgeon experience on 5-year outcome of laparoscopic Nissen fundoplication. *Arch Surg.* 2011;146:340–346.
53. Kronowitz SJ, Robb GL. Radiation therapy and breast reconstruction: a critical review of the literature. *Plast Reconstr Surg.* 2009;124:395–408.
54. Recht A, Come SE, Henderson IC, et al. The sequencing of chemotherapy and radiation therapy after conservative surgery for early-stage breast cancer. *N Engl J Med.* 1996;334:1356–1361.
55. McCarthy CM, Mehrara BJ, Riedel E, et al. Predicting complications following expander/implant breast recon-

struction: an outcomes analysis based on preoperative clinical risk. *Plast Reconstr Surg.* 2008;121:1886–1892.
56. Goodwin SJ, McCarthy CM, Pusic AL, et al. Complications in smokers after postmastectomy tissue expander/implant breast reconstruction. *Ann Plast Surg.* 2005;55: 16–19; discussion 19–20.
57. Isogai N, Fujii S, Tsukahara T, et al. Effect of hypertension on arterial structure and wound repair at the microvascular anastomosis site using stroke-prone spontaneously hypertensive rats (SHRSP). *Microsurgery* 1993;14:501–507.
58. Armstrong DG, Meyr AJ. Wound Healing and Risk Factors for Non-healing. Waltham, Mass.: UpToDate. Available at: http://www.uptodate.com. Accessed March 28, 2014.
59. Falanga V. Wound healing and its impairment in the diabetic foot. *Lancet* 2005;366:1736–1743.
60. Fischer JP, Wes AM, Tuggle CT III, et al. Risk analysis of early implant loss after immediate breast reconstruction: a review of 14,585 patients. *J Am Coll Surg.* 2013;217:983–990.
61. Lin KY, Johns FR, Gibson J, et al. An outcome study of breast reconstruction: presurgical identification of risk factors for complications. *Ann Surg Oncol.* 2001;8:586–591.
62. Fallowfield LJ, Baum M, Maguire GP. Effects of breast conservation on psychological morbidity associated with diagnosis and treatment of early breast cancer. *Br Med J (Clin Res Ed).* 1986;293:1331–1334.
63. Greer S, Morris T, Pettingale KW. Psychological response to breast cancer: effect on outcome. *Lance* 1979;2:785–787.
64. Green BL, Rowland JH, Krupnick JL, et al. Prevalence of posttraumatic stress disorder in women with breast cancer. *Psychosomatics* 1998;39:102–111.
65. Rosson GD, Shridharani SM, Magarakis M, et al. Quality of life before reconstructive breast surgery: a preoperative comparison of patients with immediate, delayed, and major revision reconstruction. *Microsurgery* 2013;33:253–258.
66. Sweeney JF. Postoperative complications and hospital readmissions in surgical patients: an important association. *Ann Surg.* 2013;258:19–20.
67. The Patient Protection and Affordable Care Act, HR 3590, 111th Congress, 2nd Session (2010). http://www.gpo.gov/fdsys/pkg/PLAW-111publ148/pdf/PLAW-111publ148.pdf. Accessed November 26, 2013.
68. Lawson EH, Hall BL, Louie R, et al. Association between occurrence of a postoperative complication and readmission: implications for quality improvement and cost savings. *Ann Surg.* 2013;258:10–18.