Journal of Plastic, Reconstructive & Aesthetic Surgery (2019) 72, 225–231

JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

A large-volume academic center retrospective audit of the temporal evolution of immediate breast reconstruction protocols and the effect on breast prosthetic infection

Michele A. Manahan[a,*], Colton H. McNichols[a], Ricardo J. Bello[a], Katherine Giuliano[a], Sherlly Xie[b], Nicholas von Guionneau[c], Jong Ahn[c], Gedge D. Rosson[a], Helen G. Hui-Chou[a]

[a] *Department of Plastic Surgery, Johns Hopkins University School of Medicine, 601 N. Caroline St., Baltimore, MD 21287, United States*
[b] *Drexel University School of Public Health, 3215 Market St., Philadelphia, PA 19104, United States*
[c] *South Kensington Campus, Imperial College School of Medicine, London SW7 2AZ, UK*

Received 29 January 2018; accepted 28 October 2018

KEYWORDS
Tissue expander infection;
Acellular dermal matrix;
Infection control protocol;
Breast reconstruction complications

Summary *Background:* Complications of tissue expanders (TEs) in breast reconstruction are challenging. We sought to identify TE infection risks and acellular dermal matrix (ADM) and infection control protocol impacts on infection in a longitudinal study.
Methods: We retrospectively analyzed TE/implant reconstructions in 2004 (no ADM), 2009 (TE and ADM), 2013 (TE, ADM, and infection control protocol), and 2015 (TE, ADM, and infection control protocol). We assessed demographic, disease, and operative factors and analyzed rates of seroma, hematoma, skin necrosis, and infection. Statistical analysis, including simple and multivariable logistic regression, was performed using Stata v13.1.
Results: 478 TEs were placed in 324 women, with a 30% overall patient complication rate (23% of breasts). A total of 14% of TEs became infected. Although unadjusted analysis showed no ADM and infection association ($p = 0.269$), multivariable logistic regression showed a significant association with more infections (OR: 3.21; 95% CI: 1.13-9.313; $p = 0.029$). The infection control

Abbreviations: TE, Tissue expander; BMI, Body mass index; ADM, Acellular dermal matrix; CUSP, Comprehensive unit-based safety program.

* Corresponding author.
E-mail address: mmanahan@jhmi.edu (M.A. Manahan).

https://doi.org/10.1016/j.bjps.2018.10.009

protocol decreased infections by 28% (16% in 2009 vs 11% in 2013); however, this did not achieve statistical significance (unadjusted $p = 0.192$, adjusted $p = 0.156$). Seroma ($p < 0.001$), older age ($p = 0.040$), larger mastectomy volume ($p = 0.001$), smoking ($p = 0.037$), BMI ($p < 0.001$), vascular disorders ($p = 0.007$), and hypertension ($p < 0.001$) significantly increased infections.
Conclusions: Identifiable risks exist in TE/implant breast reconstruction. ADM infection risk may mitigate some potential benefits. Anti-infection protocols may reduce infections, and further investigation may reveal the most effective prophylactic strategies. Absence of major changes in complications over time supports validity of studies examining large numbers of despite evolution of techniques.

Introduction

Breast cancer is the most commonly diagnosed cancer amongst women, accounting for 29% of all new cancer diagnoses in women.[1] Tissue expander (TE) and implant-based reconstruction are the most common methods of postmastectomy breast reconstruction.[2] As compared to autologous reconstruction, TE/implant-based reconstruction allows shorter operations and no donor-site morbidity.[3] Prosthetic-based reconstruction, however, is not without its own risks, reported at rates up to 20%, including wound healing problems, hematoma, seroma, infection, and reconstructive failure.[4-10]

Infection is particularly devastating, potentially requiring antibiotics and additional surgery, adding significant cost to the reconstruction,[4,5] and possibly resulting in reconstructive failure.[6] Reported infection rates vary from as low as 3% to as high as 20%, and failure rates range from 1% to 3%, usually due to infection.[4,6,7] Several factors have been suggested to increase the risk of TE/implant complications, including tobacco use, obesity (Body Mass Index > 30), and radiation therapy.[8,9,10] Efforts continue to reduce the burden of these complications. Prophylactic measures include perioperative antibiotics, postoperative antibiotics, and irrigating the surgical pocket or expander with antiseptic or antimicrobial solution before insertion.[11]

Acellular dermal matrix (ADM) began to be used over ten years ago during placement of TEs in an effort to improve reconstructive outcomes. Its purported benefits include improved inferior-lateral pole coverage, ability to inject greater initial fill volumes, and thus shorten subsequent tissue expansion, and improved aesthetic outcomes.[12-14] As the experience with ADM in TE breast reconstruction grew, however, there were reports in the literature of significant increases in complication rates, particularly infections.[13] Other studies have shown no difference in infectious and other complications when comparing TE reconstructions with and without ADM.[10,15,16]

In this study, we sought to identify potential risk factors for infection with TE-based reconstruction and to examine if infection rates were altered by the introduction of ADM or by the implementation of an infection control protocol. We hypothesized that the addition of ADM would not significantly alter complication rates, whereas the implementation of the infection control protocol would meaningfully reduce infectious complications.

Methods

With Institutional Review Board approval, we retrospectively analyzed six-month cohorts of patients undergoing staged TE reconstructive surgery at the time of mastectomy in the years 2004, 2009, 2013, and 2015. We collected patient demographics, medical comorbidities, such as diabetes mellitus, body mass index (BMI), smoking status, and history of radiation and/or chemotherapy. Operative factors including type of mastectomy, weight of breast tissue removed, use of ADM, and TE fill volumes were also analyzed. We assessed postoperative complications including infection (clinical cellulitis and/or purulent drainage from wound requiring antibiotic therapy $\pm$ surgical washout and removal of expander), hematoma, seroma (a collection of peri-prosthetic fluid not necessarily requiring operative drainage), and mastectomy skin flap necrosis (tissue of questionable or poor viability based on clinical parameters).

Statistical analysis was performed using Stata v13.1 (StataCorp LP, College Station, TX). Continuous demographic variables (such as age and BMI) were compared across the cohorts using ANOVA or Kruskal–Wallis test, as appropriate. Categorical demographic variables (such as smoking status and presence of medical comorbidities) were compared across the cohorts using Fisher's exact test or Chi-squared test, as appropriate.

All reconstructions performed in 2013 and 2015 followed an institution specific infection control protocol developed through grass-roots efforts of perioperative stakeholders through the Comprehensive Unit-based Safety Program (CUSP). The CUSP protocol includes standardized chlorhexidine skin preparation, use of Ioban (© 3 M 2016. All rights reserved.) in draping the operative field, antibiotic irrigation of operative site and soaking the prosthetic device in antibiotic solution, one person/new glove prosthesis handling, re-draping of the operative field just prior to prosthesis handling, standard preoperative antibiotic dose with postoperative antibiotics administered until drain removal, and use of the Biopatch (© Ethicon US, LLC), an antiseptic-soaked wafer, around drain sites.

The primary outcome assessed was infection. The two main exposure variables of interest were use of ADM and implementation of an infection control protocol. Univariate analysis assessed associations between demographic, peri-, and post-operative factors and odds of infection, using *t*-test or Wilcoxon rank sum test, as appropriate, for continuous variables and Chi-squared test or Fisher's exact test, as appropriate, for categorical variables. Complication rates

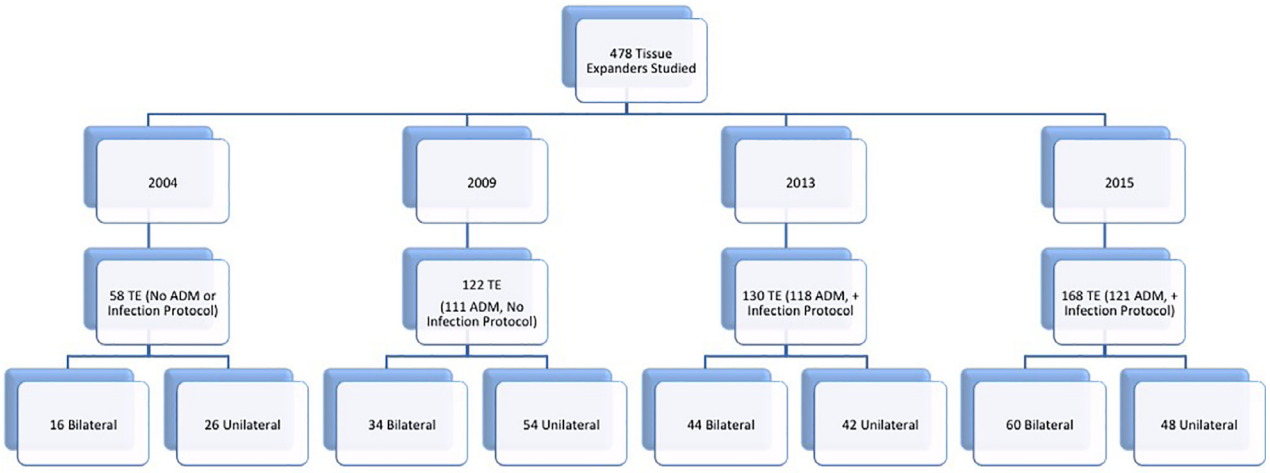

Figure 1 Breakdown of tissue expanders placed in 2004 (no alloderm or infection protocol), 2009 (with 91% alloderm), 2013 (with 91% alloderm and 100% infection protocol), and 2015 (with 71% alloderm and 100% infection protocol).

Table 1 Demographics, Comorbidities, and Surgical factors of patients undergoing postmastectomy tissue expander (TE) based reconstruction in 2004 ($n=42$), 2009 ($n=88$), 2013 ($n=86$), and 2015 ($n=108$).

Patient Demographics - N	2004	2009	2013	2015	P value
Women	42	88	86	108	-
Breasts/TE	58	122	130	168	-
Mean (SD)					
Age, years	46 (11.6)	49 (7.4)	50 (10.5)	52 (10.6)	0.006
Body mass index	26 (5.8)	27 (5.8)	26 (5.1)	27 (5.4)	0.348
Patient Comorbidities - N (%)					
Hypertension	11 (26)	32 (36)	16 (19)	31 (30)	0.070
Smoking	4 (9)	15 (17)	7 (8)	8 (8)	0.139
Diabetes mellitus	2 (5)	7 (8)	4 (5)	3 (3)	0.444
Immunosuppression	2 (5)	2 (2)	5 (6)	7 (7)	0.545
Vascular disease	1 (2)	4 (5)	1 (1)	7 (7)	0.252
Hypercoagulability	1 (2)	1 (1)	1 (1)	1 (1)	0.920
Surgical Factors - N (%)					
ADM	0	111 (91%)	118 (91%)	121 (73%)	<0.001
Mean (SD)					
Breast tissue removed (g)	343 (196)	722 (469)	540 (294)	631 (432)	0.008
TE final fill volume (cm^3)	132 (102)	211 (125)	175 (118)	342 (180)	< 0.001

for hematoma, seroma, and skin necrosis were also calculated. A multivariable logistic regression model was fitted to estimate the association between the odds of developing TE infections and use of ADM, adjusting for age, BMI, breast volume, diabetes, and hypertension. A similar model was fitted to estimate the association between the odds of infection and implementation of an infection control protocol, adjusting for age, BMI, breast volume, diabetes, hypertension, and use of ADM. Odd ratios from these models are presented with 95% confidence intervals. A p-value of equal or less than 0.05 was considered statistically significant.

Results

Over the study period, 478 TEs were placed in 324 women (Figure 1, Table 1). In six-months in 2004, 42 women underwent TE-based reconstruction (16 were bilateral, $n=58$ breasts) with no ADM used. In the same amount of time in 2009, 122 TEs were placed in 88 patients (34 bilateral). ADM was used in 91% ($n=111$) of breasts. The six-month 2013 cohort consisted of 86 women with 130 TEs (44 bilateral) following the CUSP infection control protocols (100%), with utilization of ADM in 91% ($n=118$) of breasts. In 2015, the cohort consisted of 108 women and 168 TEs (60 bilateral) with 72% using ADM ($n=121$).

Cohorts were similar across several domains, including average BMI, tobacco use, and medical comorbidities. Average BMI fell in the high normal to overweight category. 10% of patients (34 of 324) were active smokers. A total of 16 patients (5%) had diabetes mellitus, 13 (4%) had vascular disease (coronary artery disease and/or peripheral vascular disease), 4 (1%) were hypercoagulable, and 16 (5%) were immunosuppressed. The most common medical comorbidity

Table 2 Complication rates per tissue expander placed in 2004, 2009, 2013, and 2015.

Complication – N (%)	2004	2009	2013	2015	*P* Value	Total, All Patients
Infection	9 (16)	20 (16)	14 (11)	22 (13)	0.599	65 (14)
Seroma	6 (10)	14 (12)	11 (9)	16 (10)	0.883	47 (10)
Skin flap necrosis	0 (0)	9 (7)	13 (10)	8 (5)	0.053	30 (6)
Hematoma	1 (2)	6 (5)	4 (3)	6 (4)	0.727	17 (4)
Total, any complication	15 (26)	32 (26)	27 (21)	38 (23)	0.729	112 (23)

Table 3 Univariate analysis of factors affecting rate of infection.

Variable	Group	No Infection – N (%)	Infection – N (%)	*P* Value
Year	2004	49 (85)	9 (16)	0.600
	2009	102 (84)	20 (16)	
	2013	116 (89)	14 (11)	
	2015	143 (87)	22 (13)	
Acellular dermal matrix used	Yes	110 (89)	13 (11)	0.269
	No	300 (86)	51 (15)	
Smoking	Yes	374 (88)	53 (12)	0.036
	No	36 (77)	11 (23)	
Hypertension	Yes	312 (90)	34 (10)	<0.001
	No	98 (77)	30 (23)	
Vascular disease	Yes	396 (87)	57 (13)	0.007
	No	14 (67)	7 (33)	
Diabetes mellitus	Yes	392 (87)	59 (13)	0.236
	No	18 (78)	5 (22)	
Preoperative radiation	Yes	372 (88)	53 (13)	0.092
	No	37 (79)	10 (21)	
Postoperative radiation	Yes	339 (87)	52 (13)	0.570
	No	70 (84)	13 (16)	
Preoperative chemotherapy	Yes	339 (88)	48 (12)	0.140
	No	71 (82)	16 (18)	
Postoperative chemotherapy	Yes	280 (85)	51 (15)	0.103
	No	129 (90)	14 (10)	
Age (mean years $\pm$ SD)		49 ± 0.5	52 ± 1.3	0.039
Breast volume removed (mean grams $\pm$ SD)		576 ± 21	781 ± 66	0.001
Type of mastectomy	Modified Radical	324 (86)	51 (14)	0.778
	Simple	84 (87)	12 (13)	
Seroma	Yes	389 (91)	38 (9)	<0.001
	No	21 (45)	26 (55)	
Skin Flap Necrosis	Yes	393 (89)	51 (12)	<0.001
	No	17 (57)	13 (43)	

was hypertension, occurring in 28% (90 of 324) of the study population.

Significant differences between cohorts included age, mastectomy weight, and TE fill volume. Patients demonstrated increasing age at reconstruction over time. Average mastectomy weight varied (mean breast tissue removed in grams; 2004 vs. 2009 vs. 2013 vs. 2015; 343 ± 195 vs. 722.5 ± 472 vs. 539 ± 294 vs. 630 ± 293.6; $p = 0.008$) as did average intraoperative TE fill volume. Patients in 2009, 2013, and 2015 (when ADM was utilized) possessed larger mastectomy weights and average fill volumes than those in 2004 (no ADM). The most recent cohort demonstrated the largest average intraoperative TE fill volumes (mean volume in cubic centimeters; 2004 vs. 2009 vs. 2013 vs. 2015; 132 ± 102 vs. 211 ± 125 vs. 175 ± 118 vs. 342 ± 180; $p < 0.001$).

Complication rates (Table 2)

Overall, 112 of 478 breasts (23%) had one or more perioperative complications, including infection, hematoma, seroma, and/or mastectomy skin flap necrosis. Complications were recorded when the treating physician documented potential concern with a very low index of clinical suspicion. Infection occurred most commonly in 14% (65 of 478) of breasts. Seroma was the second most common complication, occurring in 47 reconstructions (10%). In 30 breasts (6%), there

Table 4 Multivariate analysis of factors associated with rate of infection.

Variable		Odds Ratio	(95% CI)	*P* Value
Year	2004	5.80	(0.39-86.73)	0.203
	2009	*Baseline*		
	2013	0.72	(0.31-1.71)	0.462
	2015	0.84	(0.39-1.84)	0.666
Smoking		2.05	(0.81-5.17)	0.129
Age		1.16	(0.81-1.66)	0.426
BMI class		1.47	(1-2.15)	0.052
ADM		3.34	(1.05-10.67)	0.042
Breast volume		1.14	(0.79-1.66)	0.484
Hypertension		1.79	(0.86-3.72)	0.119
Diabetes mellitus		1.36	(0.39-4.79)	0.629

was mastectomy skin flap necrosis, and hematoma complicated 17 reconstructions (4%).

In 2004, only 11% of patients experiencing infections also experienced another complication, whereas this proportion was higher in 2009 (60%), 2013 (71%), and 2015 (55%). Among the nine infected breasts in 2004, one (11%) also had seroma and none had hematoma or skin necrosis. Among the 20 infected breasts in 2009, one (5%) was also complicated by hematoma, nine (45%) by seroma, and seven (35%) by partial skin flap necrosis. Among the 14 infected breasts in 2013, there were six (46%) seromas, five partial skin flap necrosis and one full skin flap necrosis (total six patients, 46%), and no hematomas.

Factors affecting infection (Tables 3 and 4)

Infection rates remained similar over the four time periods ($p = 0.60$). Rates were 16% in 2004, 16% in 2009, 11% in 2013, and 13% in 2015. Both years after CUSP implementation (2013 and 2015) were lower than 2004 and 2009, but multivariate logistic regression did not provide meaningful support for this trend ($p = 0.273$).

ADM, BMI, and concomitant complications impacted infection. Of the 20 infected TEs in 2009 and the 14 infected TEs in 2013, all had ADM use, and only four of the 22 infected TEs placed in 2015 did not use ADM. Unadjusted analysis did not associate ADM with infection ($p = 0.271$), but multivariate logistic regression showed a statistically significant 3-fold increase in odds of infection with ADM (OR: 3.34, 95% CI: 1.05-10.67, $p = 0.042$). The mean BMI (using WHO classifications) was higher in patients experiencing infections (OR 1.73, 95% CI 1.28-2.34, $p < 0.001$). This effect was supported in multivariate regression ($p = 0.052$). Concomitant infections occurred in 55% of breasts with seromas ($p < 0.001$) and 43% of breasts with skin flap necrosis ($p < 0.001$).

Several factors appeared significant on univariate analysis alone. The mean age of infected patients was higher ($p = 0.039$) as was mastectomy weight ($p = 0.001$). A total of 23% of smokers developed infections, whereas 12% of nonsmokers became infected ($p = 0.036$). A total of 23% of TEs in women with hypertension developed infections compared to 10% in those without hypertension ($p < 0.001$). Vascular disease also increased odds of infection, ($p = 0.007$). Notable factors that did not significantly impact infection rates included diabetes mellitus, post-mastectomy radiation, neoadjuvant or adjuvant chemotherapy, and type of mastectomy (modified radical vs. simple). Previous radiation demonstrated a not statistically significant trend toward increased infections, (21% vs. 13%, $p = 0.092$).

Discussion

In our cohorts of 324 women and 478 TEs spanning over a decade, complications (including infection, seroma, hematoma, and mastectomy skin flap necrosis) occurred in 23% of breasts. This overall rate is higher than previous reports[4-10] but may reflect our inclusion of minor complications such as small seromas that resolved without significant morbidity. Our complication definitions were purposely broad, encompassing even early clinical concern. We believe even this heightened concern leads to more intense monitoring, impacting patient stress and cost of care, and it is therefore relevant to study.

We specifically compared infection rates between four-timed cohorts of patients over a decade to assess the impacts of ADM and an infection control protocol. Our overall infection rate (14%) matches other reports.[4-10] Our longitudinal results demonstrate impact of practice changes on outcomes over time.

Our multivariate analysis showed that the use of ADM *was* significantly associated with increased infection rates ($p < 0.042$). Several authors have also demonstrated increased complications with ADM,[13,17,18] while others have not.[19] While the associated increased initial TE fill volumes we demonstrated in our ADM cohorts are usually considered a benefit to off-set the infectious risk,[12-14] the potential negative impacts on skin perfusion should not be discounted. We believe TE fill volume associated impacts on outcomes like perfusion merit further study.

Khansa et al. demonstrated improvement in periprosthetic infection rates using an infection control protocol.[20] We demonstrated decreasing odds of infection by 28% in our post CUSP infection control protocol 2013 and 2015 cohorts, though this difference did not reach statistical significance. The effects may help to balance expanding inclusion criteria to older patients with larger breasts. Future studies will explore these interrelationships more specifically.

We also found that seroma and mastectomy skin flap necrosis were themselves associated with increased infection risks. Parks et al. previously reported that the presence of seroma increased the odds of TE loss nearly five times,[21] with the seroma being a potential nidus for infection.[17] Skin necrosis has similarly been associated with infection as well as an increased risk for TE loss.[8,21] These findings may impact future technique evolution choices as we expand indications to a wider population of less ideal patients, increase fill volumes for immediate implant reconstruction, and consider prepectoral implant placements, all of which have potentials to impact skin necrosis and seroma rates.

Our univariate results revealed risk factors for complications in keeping with the existing literature. Tobacco use in our cohorts increased the odds of developing infection by 2.2 times. Previous literature has also demonstrated not only an increased risk for infection, but also an increased risk for TE loss, wound disruption, and reconstructive failure (with similar odds ratios of between 2.2 and 4)[2,9,10,16,22] through tissue ischemia from nicotine,[23] a particular concern in mastectomy skin flaps that have been deprived of vascular support from underlying parenchyma. Increasing BMI increased complications in our patients. Nearly all previously published studies confirm this finding, with increasing BMI, particularly BMI $>$ 30, predictive of complications including infection, wound disruption, flap failure, TE loss, and reconstructive failure.[2,9,13,16,20,22,24] The increased dead space in large volume mastectomy defects associated with obesity predisposes to complications such as seroma and infection, but high fill volumes to eliminate this dead space can cause perfusion defects, which also increase complication risk.[23] As with previous studies, our cohort demonstrated increased complication rates in hypertensive patients.[2,9] Interestingly, patients with vascular disease also had higher infection rates in our analysis. Older age has previously been suggested to increase the risk of complications which also correlated with our results.[16]

These risk factors may merit caution when counseling about reconstructive options. Increased risk profiles and the ensuing potential complications may not be acceptable to many women. Our longitudinal results suggest that complications have not been mitigated by current best efforts to do so, warranting careful consideration of reconstruction choices.

We found no impact of radiation, radiation timing, or chemotherapy on outcomes. While several studies support absence of negative impacts of chemotherapy,[7,25,26] the literature is mixed on influence of radiation. Several authors have shown major negative consequences of radiation treatment with odds ratios for complications up to five,[7,12,25] while others have failed to demonstrate an effect.[6] While diabetes mellitus is usually considered to increase the risk,[6] we did not see a significant association with complications in our cohort.

This study has several limitations. First, data were collected retrospectively by year of reconstruction. Furthermore, all patients in this study are from a single institution, potentially limiting the generalizability of the findings.

However, we believe that our findings do support validity of analyses that incorporate longitudinal cohorts despite changing techniques. Impacts on complications are multifactorial. Despite high awareness and intensive efforts to minimize complications, negative outcomes still occur with regularity. Careful consideration of reconstructive modality in the presence of risk factors is warranted.

Conclusion

Our analysis of 478 TEs placed in 324 postmastectomy patients over 10 years demonstrates that complication rates of TE-based reconstruction remain high with 23% of breasts experiencing complications. We demonstrated that ADM is substantially associated with increased infections, in addition to smoking, increasing BMI, increasing age, increasing mastectomy volume, hypertension, and vascular disease. Furthermore, despite implementation of an infection control protocol, our infection rate did not statistically significantly decrease. In summary, more research is needed to identify ways to decrease infections and subsequent morbidity in TE/implant-based postmastectomy breast reconstruction. Use of this reconstructive modality when risk factors are present must be carefully considered.

Conflict of interest

N/A.

Funding

N/A.

References

1. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2015. *CA Cancer J Clin* 2015;**65**:5–29.
2. Fischer JP, Nelson JA, Serletti JM, Wu LC. Peri-operative risk factors associated with early tissue expander (TE) loss following immediate breast reconstruction (IBR): A review of 9305 patients from the 2005-2010 ACS-NISQIP datasets. *J Plast Reconstr Aesthet Surg* 2013;**66**(11):1504–12.
3. Fischer JP, Wes AM, Nelson JA, et al. Propensity-matched, longitudinal outcomes analysis of complications and cost: Comparing abdominal free flaps and implant-based breast reconstruction. *J Am Coll Surg* 2014;**219**(2):303–12.
4. Leyngold MM, Stutman RL, Khiabani KT, et al. Contributing variables to post mastectomy tissue expander infection. *Breast J* 2012;**18**(4):351–6.
5. Olsen MA, Chu-Ongsakul S, Brandt KE, Dietz JR, Mayfield J, Fraser VJ. Hospital-associated costs due to surgical site infection after breast surgery. *Arch Surg* 2008;**143**(1):53–60.
6. Kato H, Nakagami G, Iwahira Y, et al. Risk factors and risk scoring tool for infection during tissue expansion in tissue expander and implant breast reconstruction. *Breast J* 2013;**19**(6):618–26.
7. Cordeiro PG, McCarthy CM. A single surgeon's 12-year experience with tissue expander/implant breast reconstruction: Part I. A prospective analysis of early complications. *Plast Reconstr Surg* 2006;**118**(4):825–31.
8. Francis SH, Ruberg RL, Stevenson KB, et al. Independent risk factors for infection in tissue expander breast reconstruction. *Plast Reconstr Surg* 2009;**124**(6):1790–6.
9. McCarthy CM, Mehrara BJ, Riedel E, et al. Predicting complications following expander/implant breast reconstruction: An

outcomes analysis based on preoperative clinical risk. *Plast Reconstr Surg* 2008;**121**(6):1886–92.
10. Ibrahim AM, Shuster M, Koolen PG, et al. Analysis of the national surgical quality improvement program database in 19,1000 patients undergoing implant-based breast reconstruction complication rates with acellular dermal matrix. *Plast Reconstr Surg* 2013;**132**(5):1057–66.
11. Viola GM, Raad II, Rolston KV. Breast tissue expander-related infections: Perioperative antimicrobial regimens. *Infect Control Hosp Epidemiol* 2014;**35**(1):75–81.
12. Pittet B, Montandon D, Pittet D. Infection in breast implants. *Lancet Infect Dis* 2005;**5**(2):94–106.
13. Weichman KE, Wilson SC, Weinstein AL, et al. The use of acellular dermal matrix in immediate two-stage tissue expander breast reconstruction. *Plast Reconstr Surg* 2012;**129**(5): 1049–1058.
14. Slavin SA, Lin SJ. The use of acellular dermal matrices in revisional breast reconstruction. *Plast Reconstr Surg* 2012;**130**(5):70S–85S.
15. Preminger BA, McCarthy CM, Hu QY, Mehrana BJ, Disa JJ. The influence of AlloDerm on expander dynamics and complications in the setting of immediate tissue expander/implant reconstruction. *Ann Plast Surg* 2008;**60**(5):510–13.
16. Seth AK, Hirsch EM, Fine NA, Kim JY. Utility of acellular dermis-assisted breast reconstruction in the setting of radiation: A comparative analysis. *Plast Reconstr Surg* 2012;**130**(4): 750–758.
17. Newman MI, Swartz KA, Samson MC, Mahoney CB, Diab K. The true incidence of near-term postoperative complications in prosthetic breast reconstruction utilizing human acellular dermal matrices: A meta-analysis. *Aesthet Plast Surg* 2011;**35**(1):100–6.
18. Kim JY, Davila AA, Persing S, et al. A meta-analysis of human acellular dermis and submuscular tissue expander breast reconstruction. *Plast Reconstr Surg* 2012;**129**(1):28–41.
19. Nahabedian MY. AlloDerm performance in the setting of prosthetic breast surgery, infection, and irradiation. *Plast Reconstr Surg* 2009;**124**(6):1743–53.
20. Khansa I, Hendrick RG, Shore A, Meyerson J, Yang M, Boehmler JH. Breast reconstruction with tissue expanders: Implementation of a standardized best-practices protocol to reduce infection rates. *Plast Reconstr Surg* 2014;**134**(1):11–18.
21. Parks JW, Hammond SE, Walsh WA, Adams RL, Chandler RG, Luce EA. Human acellular dermis versus no acellular dermis in tissue expansion breast reconstruction. *Plast Reconstr Surg* 2012;**130**(4):739–46.
22. Lovecchio F, Jordan SW, Lim S, Fine NA, Kim JY. Risk factors for complications differ between stages of tissue-expander breast reconstruction. *Ann Plast Surg* 2015;**75**(3):275–80.
23. Goodwin SJ, McCarthy CM, Pusic AL, et al. Complications in smokers after post-mastectomy tissue expander/implant based reconstruction. *Ann Plast Surg* 2005;**55**(1):16–19.
24. Hanwright PJ, Davila AA, Hirsch EM, et al. The differential effect of BMI on prosthetic versus autogenous breast reconstruction: A multivariate analysis of 12,986 patients. *Breast* 2013;**22**(5):938–45.
25. Nahabedian MY, Tsangaris T, Momen B, Manson PN. Infectious complications following breast reconstruction with expanders and implants. *Plast Reconstr Surg* 2003;**112**(2):467–76.
26. Rundell VL, Beck RT, Wang CE, et al. Complication prevalence following use of tutoplast-derived human acellular dermal matrix in prosthetic breast reconstruction: A retrospective review of 203 patients. *J Plast Reconstr Aesthet Surg* 2014;**67**(10):1345–51.