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Research Article

The Effect of Intraoperative Submaximal Tissue Expander Inflation on Outcomes in Two-stage Prosthetic Breast Reconstruction: Less is More?

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Abstract

Background: In tissue expander-based breast reconstruction, the tissue expander is usually inflated to the maximum tissue tolerance. This maximal intraoperative inflation often affects perfusion of the mastectomy flap. This study evaluated the outcomes of patients treated with a ‘submaximal inflation protocol’ relative to the conventional maximum inflation protocol.

Methods: Patients undergoing tissue expander-based breast reconstruction between 2016 and 2018 were sorted into two cohorts according to their intraoperative inflation protocol. Of the four reconstructive surgeons, three followed the conventional inflation protocol (Cohort 2). The other surgeon adopted the submaximal inflation protocol, which involved inflating the expander about 10% less than usual (Cohort 1). Complication rates and postoperative inflation courses were assessed.

Results: In total 780 cases including 384 in Cohort 1 and 396 in Cohort 2 were analyzed. The two cohorts had similar characteristics, except for the rate of acellular dermal matrix (ADM) use. In cases without ADM, Cohort 1 was associated with significantly reduced rates of seroma, wound dehiscence, and overall complications relative to Cohort 2. These differences remained significant after adjusting for other variables. Similarly, in cases using ADM, multivariate analyses revealed Cohort 1 had significantly lower rates of seroma and wound revision. The mean single-visit inflation volume and the final inflation volume were similar between the cohorts. Cohort 1 visited the clinic more frequently for inflation than Cohort 2 regardless of ADM use.

Conclusions: Submaximal intraoperative inflation of the tissue expander may be a reliable protocol, as it reduces complication rates and allows for sufficient postoperative expansion.

Keywords: Breast implant; Breast reconstruction; Surgical Outcomes; Seroma; Tissue expander

Abbreviations: ADM: Acellular Dermal Matrix; BMI: Body Mass Index

Introduction

Two-stage tissue expander-based modality has been a leading option for breast reconstruction worldwide. Its popularity is attributable to several advantages including its relatively easy and uncomplicated nature, an acceptably low complication rate, and reliable and aesthetically satisfactory outcomes [1,2]. To further reduce postoperative complications and to improve final outcomes, constant efforts have been made on the technical specifications in several aspects. A traditional subject of debate over the use of Acellular Dermal Matrix (ADM) versus total muscular coverage [3,4], and a recently heated issue of prepectoral versus subpectoral placement of the tissue expander [5,6], are representative topics. The optimal intraoperative inflation volume has been also the subject of controversy. Traditionally, intraoperatively inflating the tissue expander to the tolerance of the overlying mastectomy skin flap has been considered the best way to preserve the original breast footprint and prevent skin shrinkage, leading to good aesthetic outcomes [7]. Moreover, maximum expansion has been thought to decrease the frequency of outpatient visits for inflation and the amount of postoperative expansion, which could reduce the patient discomfort. However, reconstructive surgeons have expressed their concern that a large tissue expansion volume could put pressure to the overlying mastectomy skin flap, thus compromising its perfusion, which may be already threatened after a total mastectomy [8]. This could eventually result in the development of mastectomy flap necrosis, which could lead to severe complications including reconstruction failure at worst.

Several clinical studies have investigated potential effects of intraoperative filling volume on complications rates after tissue expander-based breast reconstruction. However, the results of these studies have been inconsistent [9-12]. Influences of the intraoperative inflation volume on postoperative outcomes remains still unclear. We have similar impression that a greater intraoperative tissue expander volume could indeed increase the risk of postoperative complications including wound problem. Therefore, we have adopted a revised protocol for use in some patients, involving an intentionally reduced intraoperative tissue expansion volume, termed 'submaximal inflation'. This study aimed to evaluate the postoperative outcomes of patients treated with 'submaximal inflation' relative to those of patients with the conventional inflation protocol, and to investigate the influences of intraoperative inflation volume on development of complications

Patients and Methods

Study Population

Patients who underwent two-stage tissue expander-based breast reconstruction immediately following a total mastectomy at a tertiary referral center between 2016 and 2018 were identified using a prospective database. Patients receiving neo-adjuvant chemotherapy were excluded from the study, as they could have relatively higher risks of developing postoperative complications, which could act as a confounder. Two types of tissue expanders had been used during the study period: Siltex-microtextured expanders (Mentor Worldwide, Santa Barbara, Calif.) and Biocell-macrotextured expanders (Allergan, Inc, Irvine, Calif.). The former was predominantly used in the authors' institution. Thus, cases using the latter were excluded to reduce the potential confounding effects of tissue expander texture on postoperative outcomes. Four attending reconstructive surgeons conducted operations during the study period. Surgeon 2, 3, and 4 used the conventional intraoperative inflation protocol, in which the tissue expander was inflated as much as the overlying mastectomy skin flap permitted. The perfusion of mastectomy skin flap was assessed based on clinical signs. Those patients were assigned to Cohort 2, which served as the control group for the analyses below. Surgeon 1 (principal investigator) prospectively adopted the submaximal inflation protocol for his consecutive patients. The submaximal inflation protocol was defined as inflating the expander about 10 to 15 percent of the suggested full capacity less than the conventional protocol (Figure 1). Those patients were assigned to Cohort 1. This study obtained approval from the institutional review board of Samsung Medical Center. All patients gave informed consent to the operative procedures and postoperative managements.

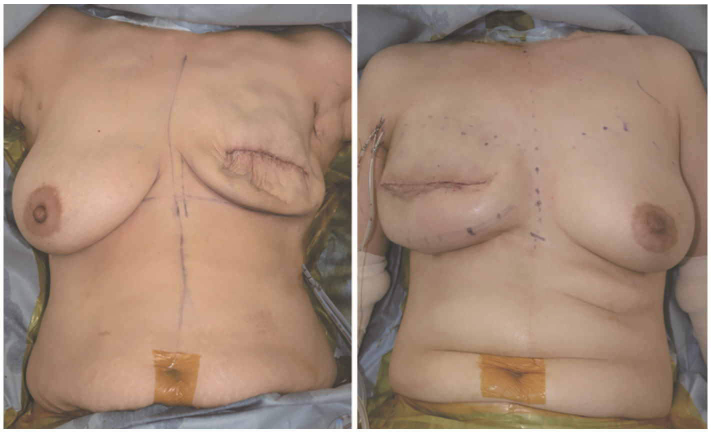

Figure 2: Scheme of extent of dead space beneath the pectoralis muscle in tissue expander-based breast reconstruction. (Left) Cases with maximal inflation. Theoretically considerable amount of dead space (blue) can remain in the cranial side of the tissue expander. (Right) Cases with submaximal inflation. The upper dead space (blue) can be relatively reduced with lesser inflation of the tissue expander.

Procedures

Breast cancer patients who were evaluated as having relatively early-stage tumors during their preoperative evaluation were referred to reconstructive surgeons for immediate reconstruction. There were no specific matchings between ablative breast surgeons and reconstructive surgeons, and patients were referred to reconstructive surgeons based on the availability of operation schedule. The tissue expander insertion following total mastectomy was conducted as usual [13]. The selection of tissue expander size was mainly based on breast width and expected breast volume. Tissue expanders were inserted into the subpectoral pocket. Its lateral aspect was covered with either ADM or with serratus anterior fascia according to the attending surgeon's preferences. Surgeon 2 rarely used ADM, while surgeon 4 used ADM for all his cases. Surgeons 1 and 3 used ADM selectively, according to intraoperative conditions including the remaining mastectomy skin flap and the extent of damage to the pectoralis major muscle and serratus anterior fascia. Other procedures were relatively standardized between the four reconstructive surgeons. Two drains were inserted during surgery: one into the subpectoral space and the other into the prepectoral space. A mild compressive dressing of fluffed gauze was then applied. Postoperatively, drains were removed when the daily output from the drains was less than 40 cc for two consecutive days. Antibiotics were administered until the drains were removed.

Outcome Measures

Patient demographics and operation-related characteristics were prospectively recorded on a database by ancillary doctors. Postoperative complications were noted by attending surgeons in their outpatient clinics and recorded in electronic medical records. The information in the database was updated monthly by ancillary doctors. Primary outcomes were the rates of complications following the 1st stage operation (tissue expander insertion) including seroma, hematoma, infection, wound dehiscence, mastectomy flap necrosis, wound revision, reoperation, and premature removal of the tissue expander. Reoperation was defined as a return to the operating room for any reason, such as wound repair or hematoma evacuation. Secondary outcomes were postoperative inflation-related outcomes including the time to 1st postoperative inflation, postoperative inflation frequency, mean single-visit inflation volume, postoperative inflation volume, final inflation volume, and final inflation ratio, which was defined as the ratio of the final inflation volume to the maximum capacity of tissue expander.

Statistical Analysis

The postoperative complication rates and inflation courses of Cohorts 1 and 2 were compared. We used the Pearson chi-square test or Fisher's exact test to analyze categorical variables and the Student's t-test or Mann-Whitney test for continuous variables. To evaluate the influence of variables on the complications, univariate and multivariate logistic regression analyses were conducted. A backward selection model was applied for the multivariate analyses. A p value of less than 0.05 was considered statistically significant. All statistical analyses were performed using SPSS version 20.0 (IBM Corporation, Armonk, NY, USA).

Results

Based on the above inclusion and exclusion criteria, a total of 734 patients representing 780 cases were included in the final analysis. There were 46 patients with bilateral reconstruction. According to the intraoperative inflation protocol, patients were categorized into two cohorts; cohort 1 (submaximal inflation protocol) containing 384 cases and cohort 2 (conventional inflation protocol) containing 396 cases. Table 1 lists the baseline characteristics of the two cohorts. The cohorts had relatively similar characteristics in terms of age, Body Mass Index (BMI), co-morbidities (diabetes and hypertension), smoking status, mastectomy types, and mastectomy specimen weights. A larger tissue expander was used in the Cohort 2, probably due to the greater weight of resected mastectomy specimens. As expected, the intraoperative inflation volume and its ratio were remarkably different between the cohorts. The average intraoperative inflation volume in Cohort 1 was approximately 50 cc smaller than in Cohort 2. The rate of ADM use was also significantly different between the two cohorts. Usually ADM use allows for a greater intraoperative tissue expansion volume,[3] which was also observed in this study (Table 2). Given that, this difference in the rate of ADM use is thus a potential confounding variable that influenced both complication rates and postoperative inflation courses. Therefore, we decided the further analysis with divided by the use of ADM or not.

Variables	Overall (n = 780)	Cohort 1 (n = 384)	Cohort 2 (n = 396)	p-value
Patient-related				
Age (yrs)	44.3 (± 7.4)	44.2 (± 7.5)	44.4 (± 7.1)	0.575
BMI (kg/m^2)	22.4 (± 2.9)	22.1 (± 2.6)	22.5 (± 3.1)	0.182
Diabetes	11 (1.4%)	3 (0.8%)	8 (2.0%)	0.142
Smoking	9 (1.2%)	5 (1.3%)	4 (1.0%)	0.703
Hypertension	32 (4.1%)	14 (3.6%)	18 (4.5%)	0.527
Prior irradiation	12 (1.5%)	6 (1.6%)	6 (1.5%)	0.957
Operation-related				
Type of mastectomy				0.269
Nipple-sparing	160 (20.5%)	85 (22.1%)	75 (18.9%)	
Skin-sparing	620 (79.5%)	229 (77.9%)	321 (81.1%)	
Wt. of mastectomy specimen	383.3 (± 181.1)	372.0 (± 167.5)	389.7 (± 195.0)	0.469
Size of tissue expander	403.0 (± 96.5)	392.2 (± 99.7)	409.6 (± 91.5)	0.003
Use of ADM	386 (49.5%)	86 (22.4%)	300 (75.8%)	< 0.001
Intraoperative inflation	96.8 (± 77.2)	70.7 (± 52.9)	121.9 (± 88.0)	< 0.001
Intraoperative inflation ratio	0.24 (± 0.16)	0.18 (± 0.11)	0.28 (± 0.18)	< 0.001

BMI: Body Mass Index; Wt: Weight; ADM: Acellular Dermal Matrix

Table 1: Patient demographics.

	Cases using ADM	Cases not using ADM	p-value
Intraop inflation volume	119.9 (± 89.2)	74.1 (± 54.6)	< 0.001
Intraop inflation ratio	0.28 (± 0.18)	0.19 (± 0.13)	< 0.001

Table 2: Differences in intraoperative inflation according to the use of ADM.

Cases without ADM use

A total of 394 cases, including 298 in Cohort 1 and 96 in Cohort 2 were analyzed. The two cohorts had similar characteristics, except for the type of mastectomy. Cohort 1 had an inflation volume of 64.1 cc with a ratio of 0.17 on average, while Cohort 2 showed a volume of 104.8 cc with a ratio of 0.27, which difference was significant. Over 80 percent of patients in Cohort 1 had an intraoperative filling of less than 25 percent of the maximal capacity of tissue expander (Table 3). The time to 1st postoperative inflation and the mean one-visit inflation volume were similar between the two cohorts. However, the postoperative inflation frequency was significantly higher in Cohort 1, as patients in Cohort 1 visited the outpatient clinic an average of one more time than patients in Cohort 2. Accordingly, the postoperative inflation volume was significantly greater in Cohort 1; however, the final inflation volume and its ratio were similar between the two cohorts (Table 4). Cohort 1 had a significantly lower rate of overall postoperative complications than Cohort 2. Especially, the rate of seroma was significantly lower in Cohort 1 relative to Cohort 2 (p = 0.003). Cohort 1 also had lower rates of delayed healing and wound dehiscence relative to Cohort 2, although this difference was not significant. Rates of other complications including infection and hematoma did not differ between the cohorts (Table 4). Multivariable analyses revealed that Cohort 1 was associated with a significantly reduced rate of overall complications relative to Cohort 2 (adjusted p = 0.001, odds ratio: 5.458, 95%, confidence intervals: 2.051 - 14.527). Age, diabetes, tissue expander size, and mastectomy type were also significantly associated with postoperative complications. Similarly, rates of seroma and wound dehiscence were significantly affected by inflation cohort after adjusting for other variables, showing a significantly reduced odds ratio in Cohort 1. Cohort 1 showed reduced rates of delayed healing and reoperation in multivariate analyses, although these associations were of borderline significance (Table 5).

Variables	Cohort 1 (n = 298)	Cohort 2 (n = 96)	p-value
Patient-related			
Age	44.1 (± 7.3)	44.5 (± 7.3)	0.835
BMI	22.1 (± 2.7)	21.7 (± 2.8)	0.158
Diabetes	2 (0.7%)	1 (1.0%)	0.716
Smoking	2 (0.7%)	2 (2.1%)	0.230
Hypertension	14 (4.7%)	3 (3.1%)	0.509
Prior irradiation	4 (1.3%)	0	0.254
Operation-related			
Type of mastectomy			0.034
Nipple-sparing mastectomy	69 (22.5%)	12 (12.5%)	
Skin-sparing mastectomy	231 (77.5%)	84 (87.5%)	
Weight of mastectomy specimen	362.5 (± 166.3)	348.6 (± 175.7)	0.321
Size of tissue expander	389.4 (± 98.1)	375.0 (± 84.8)	0.354
Intraoperative inflation volume	64.1 (± 44.0)	104.8 (± 70.8)	< 0.001
Intraoperative inflation ratio	0.17 (± 0.10)	0.27 (± 0.15)	< 0.001
categorized			< 0.001
< 0.25	241 (80.9%)	44 (45.8%)	
0.25 - 0.5	53 (17.8%)	44 (45.8%)	
0.5 - 0.75	4 (1.3%)	8 (8.3%)	
≥ 0.75	0	0	

Table 3: Comparison of patient- and operation-related characteristics between cohort 1 and 2 in cases not using ADM.

	Cohort 1	Cohort 2	p-value
Postop inflation course			
Time to 1st. inflation (days) (median)	26	27	0.302
Postop inflation frequency (median)	6	5	< 0.001
Mean inflation volume at one visit	52.9 (± 11.6)	53.2 (± 15.8)	0.933

Postop inflation volume	296.2 (± 101.4)	250.8 (± 105.4)	0.014
Final inflation volume	364.7 (± 105.4)	338.6 (± 118.9)	0.231
Final inflation ratio	0.96 (± 0.25)	0.91 (± 0.23)	0.431
Overall complication	11 (3.7%)	11(11.5%)	0.004
Infection	1 (0.3%)	1 (1.0%)	0.397
Seroma	2 (0.7%)	5 (5.2%)	0.003
Hematoma	4 (1.3%)	3 (3.1%)	0.250
Delayed healing	5 (1.7%)	3 (3.1%)	0.382
Mastectomy flap necrosis	4 (1.3%)	1 (1.0%)	0.819
Wound dehiscence	1 (0.3%)	2 (2.1%)	0.087
Wound revision	1 (0.3%)	1 (1.0%)	0.397
Re-operation	4 (1.3%)	4 (4.2%)	0.088
Premature removal of tissue expander	1 (0.3%)	0	0.570
Drain duration (days, median)	10	10	0.266

Table 4: Postoperative course of tissue expander inflation in cases not using ADM.

Variables	Adjusted p-value	OR (95% CI)
For overall complication		
Age	0.020	1.073 (1.011 - 1.139)
Diabetes	0.041	13.661 (1.109 - 168.251)
Inflation Cohort		
Cohort 1	Ref	
Cohort 2	0.001	5.458 (2.051 - 14.527)
Size of Tissue expander	0.001	1.008 (1.003 - 1.013)
Type of mastectomy		
Skin-sparing mastectomy	Ref	
Nipple-sparing mastectomy	0.012	3.877 (1.347 - 11.156)
For seroma		
Age	0.031	1.152 (1.013 - 1.310)
BMI	0.001	2.397 (1.464 - 3.924)
Inflation Cohort		
Cohort 1	Ref	
Cohort 2	0.007	32.077 (2.617 - 393.161)
For overall delayed healing		

BMI	0.015	0.621 (0.424 - 0.911)
Inflation Cohort		
Cohort 1	Ref	
Cohort 2	0.051	6.284 (0.990 - 39.880)
Mastectomy type		
Skin-sparing mastectomy	Ref	
Nipple-sparing mastectomy	0.001	16.632 (3.044 - 90.890)
Size of Tissue expander	0.001	1.017 (1.007 - 1.027)
For wound dehiscence		
BMI	0.019	0.403 (0.189 - 0.859)
Inflation Cohort		
Cohort 1	Ref	
Cohort 2	0.037	39.486 (1.250 - 1247.789)
Size of tissue expander	0.008	1.028 (1.007 - 1.049)
For re-operation		
Age	0.031	1.110 (1.010 - 1.219)
Diabetes	0.008	36.174 (2.507 - 522.009)
Inflation Cohort		
Cohort 1	Ref	
Cohort 2	0.051	4.563 (0.990 - 21.029)
Type of mastectomy		
SSM		
NSM	0.047	5.261 (1.024 - 27.045)

OR: Odds Ratio; CI: Confidence Intervals

Table 5: Multivariable analysis for independent predictors of complications in cases not using ADM.

Cases with ADM use

In total 386 cases using ADM were analyzed. In this subset of cases, Cohort 2 (300 cases) contained many more cases than Cohort 1 (86 cases). The two cohorts showed similar baseline characteristics except for rate of active smokers, which was significantly higher in the Cohort 1. The intraoperative inflation volume and its ratio to maximum inflation volume were also significantly lower in Cohort 1 relative to Cohort 2 (Table 6). Similar to the above analyses, the time to 1st inflation, mean single-visit inflation volume, and the final inflation volume and its ratio were similar between cohorts. However, Cohort 1 had a significantly higher frequency of outpatient clinic visits for inflation than Cohort 2 (median: 6 vs. 5 visits, $p < 0.001$). The overall complication rate was not significantly different between the two cohorts. However, Cohort 1 had a significantly lower rate of seroma and wound revision than Cohort 2. Rates of wound-related complications tended to be lower in Cohort 1, though the differences were not significant (Table 7). Multivariate analyses showed Cohort 1 had significantly reduced odds of developing seroma and wound revision compared to Cohort 2. Inflation protocol did not influence the rate of other complications.

Variables	Cohort 1 (n = 86)	Cohort 2 (n = 300)	p-value
Patient-related			
Age	44.8 (± 7.9)	44.4 (± 7.0)	0.815
BMI	22.2 (± 2.4)	22.8 (± 3.2)	0.218
Diabetes	1 (1.2%)	7 (2.3%)	0.502
Smoking	3 (3.5%)	2 (0.7%)	0.041
Hypertension	1 (1.2%)	15 (5.0%)	0.116
Prior irradiation	2 (2.3%)	6 (2.0%)	0.852
Operation-related			
Type of mastectomy			0.989
Nipple-sparing mastectomy	18 (20.9%)	63 (21.0%)	
Skin-sparing mastectomy	68 (79.1%)	237 (79.0%)	
Weight of mastectomy	404.6 (± 168.7)	402.8 (± 199.3)	0.566
Size of tissue expander	401.7 (± 105.4)	420.7 (± 90.9)	0.072
Intraoperative inflation volume	84.9 (± 79.9)	126.9 (± 93.3)	0.001
Intraoperative inflation ratio	0.21 (± 0.14)	0.29 (± 0.18)	< 0.001
categorized			< 0.001
< 0.25	62 (72.1%)	133 (44.3%)	
0.25 - 0.5	20 (23.3%)	127 (42.3%)	
0.5 - 0.75	4 (4.7%)	37 (12.3%)	
≥ 0.75	0	3 (1.0%)	

Table 6: Comparison of patient- and operation-related characteristics between cohort 1 and 2 in cases using ADM.

	Cohort 1	Cohort 2	p-value
Postop inflation course			
Time to 1st. inflation (days) (median)	28.0	27.5	0.287
Postop inflation frequency (median)	6	5	< 0.001
Mean inflation volume at one visit	52.5 (± 12.5)	56.1 (± 19.1)	0.105
Postop inflation volume	311.8 (± 117.3)	262.1 (± 100.3)	0.004
Final inflation volume	393.1 (± 113.2)	379.8 (± 107.7)	0.607
Final inflation ratio	1.00 (± 0.22)	0.97 (± 0.29)	0.202
Overall complication	7 (8.1%)	42 (14.0%)	0.150
Infection	3 (3.5%)	4 (1.3%)	0.187
Seroma	0	17 (5.7%)	0.024

Hematoma	3 (3.5%)	5 (1.7%)	0.296
Delayed healing	3 (3.5%)	26 (8.7%)	0.108
Mastectomy flap necrosis	1 (1.2%)	14 (4.7%)	0.138
Wound dehiscence	2 (2.3%)	16 (5.3%)	0.244
Wound revision	0	19 (6.3%)	0.017
Premature removal of tissue expander	0	0	N/A
Re-operation	3 (3.5%)	22 (7.3%)	0.202
Drain duration (days, median)	10	9	0.037

N/A: Not Applicable

Table 7: Comparison of complication profiles between cohort 1 and 2 in cases using ADM.

Discussion

With a long-standing, but still unproven presumption that a greater intraoperative inflation volume may increase the rate of postoperative complications, this study examined the effects of the submaximal inflation protocol in a prospective cohort of immediate tissue expander-based breast reconstruction. We also compared their complication profiles and postoperative inflation courses with those of patients treated with the conventional inflation protocol to evaluate whether the inflation protocol could influence outcomes independently. Intraoperative inflation volume is largely influenced by many factors including breast size, redundancy of remnant mastectomy skin flap, use of ADM, and other such factors. Most anecdotal studies have compared the intraoperative inflation volumes of patients who developed complications relative to patients who did not [9-12]. With a case-control design of these studies, it would be difficult to adjust potential interaction between those factors and related confounding effects. In this study, we used a submaximal inflation protocol for one cohort that consisted of consecutive patients treated by one surgeon. This design allowed us to analyze the independent influence of intraoperative tissue expander inflation volume in a less biased manner. As the two cohorts in our study were treated by different surgeons, inter-surgeon variability could bias several aspects including operative techniques and patient characteristics. However, procedures of tissue expander insertion are relatively less complicated and could be conducted consistently with low diversity. In fact, generally homogeneous surgical techniques and postoperative management protocol had been adopted regardless of surgeons. In addition, there was no specific matching between breast surgeons and plastic surgeons as mentioned above. As a result, the two cohorts had generally similar baseline characteristics, lessening the likelihood of bias. One thing that was remarkably different between the cohorts was the rate of ADM usage. This can influence not only the patient tolerance of the intraoperative inflation protocol, but also the postoperative outcomes. We therefore conducted further analyses stratified by ADM use to reduce its potential confounding effects.

Whether the submaximal protocol could be associated with reduced risks for wound-related problems was of great interest in the beginning of the current study. We found that rates of delayed healing, including wound dehiscence, were lower in Cohort 1 compared to Cohort 2 independently of ADM usage. Furthermore, these associations remained significant after adjusting for other variables on multivariate analyses. Cohort 1 had significantly reduced odds for wound dehiscence in cases with not using ADM and those for wound revision in cases using ADM than Cohort 2. Considering that wound dehiscence and situations requiring wound revision are usually closely related to compromised perfusion of the mastectomy skin flap, our results suggest that intraoperative submaximal tissue expander inflation might promote a favorable environment for wound healing by allowing proper perfusion of the mastectomy skin flap. While maximal inflation based on clinical decision of experienced surgeons may not usually compromise perfusion of the mastectomy skin flap itself, it might be burdensome for successful wound healing to some extent especially in cases with marginal mastectomy skin flap perfusion.

We have observed a significantly reduced rate of seroma formation in Cohort 1 relative to Cohort 2 after adjusting for other variables regardless of ADM usage. This result was unexpected because canonically the intraoperative maximal tissue expander inflation was thought to reduce dead space beneath the mastectomy skin flap, thereby decreasing the drainage period and risk of seroma formation. In this study, in cases using ADM, Cohort 1 showed a longer drainage period than Cohort 2, while in cases not using ADM, the two cohorts had similar drainage periods. When conducting maximal inflation, the lower part of the pocket is well occupied by the inflated tissue expander, however the upper space beneath the pectoralis major muscle remains vacant.

Paradoxically, this upper dead space can enlarge as the tissue expander inflation is increased. In cases with submaximal inflation, the upper dead space could be minimized theoretically because the tissue expander is less inflated (Figure 2). The potential dead space in the subcutaneous pocket caused by redundancy in the mastectomy skin flap during submaximal inflation can be reduced with negative pressure during drainage. Also development of postoperative seroma is known to be multifaceted. Delayed healing may result in sustained fluid collection after drainage removal. As suggested above, the submaximal inflation may accelerate wound healing by not compromising perfusion of the mastectomy skin flap, which can result in lower postoperative seroma rates. Further investigations are required to verify this result.

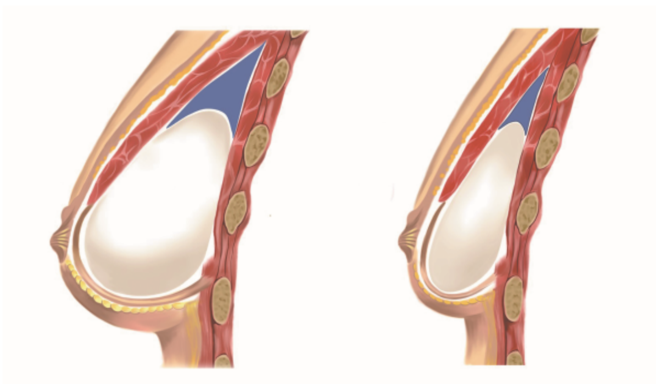

Figure 1: Intraoperative appearances of representative cases of Cohort 1 with submaximal inflation (Left) and Cohort 2 with the conventional inflation protocol (Right).

In the present study, the submaximal inflation cohort visited the outpatient clinic for inflation more frequently, averaging one more time compared to the conventional protocol cohort. This result was expected and quite plausible. Notable was that mean single-visit inflation volume and final inflation volume were similar between the cohorts regardless of ADM use. Traditionally surgeons have assumed that a less expanded skin flap may shrink and restrict postoperative expansion. However, we observed the opposite in this study, suggesting these concerns may be unnecessary. Before the active application of the submaximal inflation protocol in the clinic, a cost-benefit estimate needs to be conducted. Our results suggest the submaximal inflation protocol will reduce the risks of complications relative to the conventional protocol. However, the submaximal inflation protocol requires more frequent postoperative visits for inflation, which is not a trivial issue considering patient discomfort. Given these concerns, the selective use of this protocol in cases with high complication risks might be appropriate.

The present study has a number of limitations. As mentioned above, composition of reconstructive surgeons were heterogenous between the cohorts, possibly acting as a confounding variable. To resolve this issue, a prospective randomized controlled study involving multiple surgeons would be necessary. Although nearly 800 cases were analyzed in this study, the sample size was still not large enough to conduct a detailed subgroup analysis. Larger multicenter studies are necessary to conduct such analyses. Our study population also has a relatively lower BMI and lower rate of co-morbidities compared to other Western population. This may make it difficult to generalize our results. Finally, we did not evaluate final reconstructive outcomes after the 2nd stage operation, which is one of the main limitations of this study. We have had impression of no remarkable differences between the cohorts in this regard. However, further detailed assessment on results of the 2nd stage operation with more objective evaluation tools are necessary. Those outcomes can be influenced by multiple factors, and so well-designed controlled studies are essential.

Conclusions

Our results suggest that the submaximal intraoperative tissue expander inflation could be a safe protocol, resulting in a lower rate of postoperative complications (including seroma and wound-related complications) compared to the conventional maximal inflation protocol. It could allow for sufficient postoperative expansion, although more frequent visit for inflation are necessary. The submaximal inflation protocol could thus provide a reliable foothold upon which to conduct the 2nd stage operation.

References

1. Cordeiro PG, McCarthy CM (2006) A single surgeon's 12-year experience with tissue expander/implant breast reconstruction: part I. A prospective analysis of early complications. Plast Reconstr Surg 118: 825-831.
2. Crosby MA, Dong W, Feng L, Kronowitz SJ (2011) Effect of intraoperative saline fill volume on perioperative outcomes in tissue expander breast reconstruction. Plast Reconstr Surg 127: 1065-1072.
3. DeLong MR, Tandon VJ, Farajzadeh M, Berlin NL, MacEachern MP, et al. (2019) Systematic Review of the Impact of Acellular Dermal Matrix on Aesthetics and Patient Satisfaction in Tissue Expander-to-Implant Breast Reconstructions. Plast Reconstr Surg 144: 967e-974e.
4. Frey JD, Choi M, Salibian AA, Karp NS (2017) Comparison of Outcomes with Tissue Expander, Immediate Implant, and Autologous Breast Reconstruction in Greater Than 1000 Nipple-Sparing Mastectomies. Plast Reconstr Surg 139: 1300-1310.
5. Khavanin N, Jordan S, Lovecchio F, Fine NA, Kim J (2013) Synergistic interactions with a high intraoperative expander fill volume increase the risk for mastectomy flap necrosis. J Breast Cancer 16: 426-431.
6. Lee KT, Hong SH, Jeon BJ, Pyon JK, Mun GH, et al. (2019) Predictors for Prolonged Drainage following Tissue Expander-Based Breast Reconstruction. Plast Reconstr Surg 144: 9e-17e.
7. Lee KT, Mun GH (2016) Updated Evidence of Acellular Dermal Matrix Use for Implant-Based Breast Reconstruction: A Meta-analysis. Ann Surg Oncol 23: 600-610.

8. Mlodinow AS, Fine NA, Khavanin N, Kim JY (2014) Risk factors for mastectomy flap necrosis following immediate tissue expander breast reconstruction. J Plast Surg Hand Surg 48: 322-326.

9. Momeni A, Remington AC, Wan DC, Nguyen D, Gurtner GC (2019) A Matched-Pair Analysis of Prepectoral with Subpectoral Breast Reconstruction: Is There a Difference in Postoperative Complication Rate? Plast Reconstr Surg 144: 801-807.

10. Pusic AL, Cordeiro PG (2003) An accelerated approach to tissue expansion for breast reconstruction: experience with intraoperative and rapid postoperative expansion in 370 reconstructions. Plast Reconstr Surg 111: 1871-1875.

11. Walia GS, Aston J, Bello R, Mackert GA, Pedreira RA, et al. (2018) Prepectoral Versus Subpectoral Tissue Expander Placement: A Clinical and Quality of Life Outcomes Study. Plast Reconstr Surg Glob Open 6: e1731.

12. Yalanis GC, Nag S, Georgek JR, Cooney CM, Manahan MA, et al. (2015) Mastectomy Weight and Tissue Expander Volume Predict Necrosis and Increased Costs Associated with Breast Reconstruction. Plast Reconstr Surg Glob Open 3: e450.

13. Yang CE, Chung SW, Lee DW, Lew DH, Song SY (2018) Evaluation of the Relationship Between Flap Tension and Tissue Perfusion in Implant-Based Breast Reconstruction Using Laser-Assisted Indocyanine Green Angiography. Ann Surg Oncol 25: 2235-2240.