Safety Profiles of Fat Processing Techniques in Autologous Fat Transfer for Breast Reconstruction

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PATIENT SAFETY

Background: Autologous fat transfer is common in breast reconstruction because of its versatility for use in contour deformities. The authors examined three different fat grafting processing techniques for complications and safety profile using their institutional database.

Methods: Retrospective review was performed of patients from a single institution who had undergone autologous fat transfer following breast reconstruction from 2012 to 2016. Individuals were separated into three cohorts according to fat harvest technique: (1) centrifugation, (2) Telfa gauze, or (3) Revolve. Complications between the groups were assessed.

Results: A total of 267 cases of autologous fat transfer were identified (centrifugation, n = 168; Telfa, n = 44; and Revolve, n = 55). Grafting by means of centrifugation was associated with the greatest incidence of oil cysts (12.5 percent; $p = 0.034$), postoperative adverse events observed in the clinic (13.7 percent; $p = 0.002$), and total complications (25.6 percent; $p = 0.001$). The use of Telfa resulted in the lowest rates of oil cyst formation (0 percent; $p = 0.002$) and total complications (2.3 percent; $p = 0.001$). Grafting by means of centrifugation was also associated with the highest frequency of repeated injections among the three techniques after initial grafting (19.6 percent; $p = 0.029$). In contrast, Revolve demonstrated a repeated injection rate of just 5.45 percent, significantly lower when independently compared with centrifugation ($p = 0.011$). Multivariate analysis demonstrated that higher total graft volume ($p = 0.002$) and the use of centrifugation ($p = 0.002$) were significant risk factors for adverse events seen in the clinic postoperatively.

Conclusions: Significant differences in postoperative outcomes exist between varying fat transfer techniques. Autologous fat transfer by means of centrifugation harbored the highest rates of complication, whereas Telfa and Revolve exhibited similar safety profiles. (*Plast. Reconstr. Surg.* 143: 985, 2019.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, III.

Autologous fat transfer is a widely used technique for filling and reshaping contour anomalies for both breast reconstruction and aesthetic operations. Multiple advantages have been demonstrated, including the following: it is minimally invasive and readily available, it can be harvested easily, it is inexpensive, and adipose harvest can be performed multiple times.[1] Autologous fat transfer has been used for multiple indications, including congenital anomalies,[2] breast augmentation and reconstruction,[3–5] buttock augmentation,[6,7] facial rejuvenation, and contour abnormalities.[8] Of these, breast reconstruction/augmentation is the most common application of fat grafting in surgery. Small-volume autologous

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fat grafting is an important adjunct to improve superior pole hollowing following both autologous and alloplastic breast reconstruction.

Although the number of fat grafting procedures continues to increase at an impressive rate, the long-term viability of grafted material and the incidence of postreconstruction complications remain variable. Fat retention and viability, symptomatic fat necrosis, formation of oil cysts, and recipient-site inflammation are highly variable and difficult to predict, and lead to additional procedures and unsatisfactory clinical outcomes. Preoperative and intraoperative factors leading to such variability in outcomes are poorly understood. Moreover, there are no standardized protocols for harvesting and processing fat, making variation in processing technique a potential factor for inconsistency in fat grafting outcomes. In this study, we examine three common techniques: centrifugation, Telfa gauze (Covidien, Mansfield, Mass.), and the Revolve fat processing system (LifeCell Corp., Bridgewater, N.J.). Our study sets out to ascertain differences in complications between fat-processing techniques in a single-institution study of breast reconstruction patients.

PATIENTS AND METHODS

Patient Selection

We performed a retrospective chart review of the operative case logs on all autologous fat transfer procedures performed following breast reconstruction between 2012 and 2016. This research protocol was approved by the institutional review board. For each case identified, the online medical record was accessed for analysis of operative notes and outpatient clinic notes following surgery. Each operative note was carefully evaluated for the autologous fat processing technique before injection, and cases were segregated into three groups: (1) centrifugation, (2) Telfa, and (3) Revolve. Patients met inclusion criteria if their operative note specifically identified the fat grafting/processing technique and if they had a minimum of one clinic follow-up visit. Moreover, patients were excluded from this study if their documents were ambiguous with respect to specific grafting techniques or they did not return for postoperative follow-up.

Data regarding patient demographics, concurrent comorbidities, history of previous breast surgery, technique of prior breast reconstruction, laterality of grafting site(s), and history of adjuvant radiation therapy were carefully obtained from the online medical record and are listed in Table 1. Clinically apparent complications that were reported in the medical records were included and compared among the three treatment groups as follows: oil cyst formation, fat necrosis, and any other complication (i.e., erythema, cellulitis, prolonged edema, persistent pain, and wound discharge).

Fat Processing Techniques

Centrifugation

The centrifuge technique involves spinning the harvested fat at 1000 *g* for 3 minutes to retain the middle fat phase after removing the upper oil phase and lower aqueous phase.

Telfa

The Telfa technique is performed by rolling the lipoaspirate over Telfa gauze, allowing the aqueous portion to be absorbed by the material.[9]

Revolve

The Revolve fat processing system allows immediate segregation of tumescent fluid from fat during the collection of lipoaspirate and automatically washes and vacuum-aspirates the processed content three times before it is ready for injection.[10]

Statistical Analysis

Mean and standard deviation were used to describe normally distributed continuous variables, whereas median and interquartile range were used for nonnormally distributed variables. One-way analysis of variance was performed to determine differences in variables that follow a normal distribution, whereas the Kruskal-Wallis test was used for nonnormally distributed variables. Univariate analysis for postoperative complications was performed using the chi-square and Fisher's exact test. Moreover, the Mann-Whitney test was used to correlate fat graft volume with further complications. Multivariate analysis using a logistic regression model was used to identify predictors of overall complication. Significance was defined at $p < 0.05$. Analysis was performed using the SPSS Version 3.154 (SPSS, Inc., Chicago, Ill.).

RESULTS

A total of 267 cases of autologous fat transfer met the inclusion criteria. Of these cases, 168 underwent centrifuge processing, 44 underwent Telfa, and 55 underwent Revolve performed by one of the six surgeons. Patient demographics were largely similar in terms of race, comorbidities (i.e., hypertension,

Table 1. Demographics, Comorbidities, and Intraoperative Characteristics of Patients Undergoing the Three Techniques of Fat Processing

Characteristic	Centrifugation (%)	Telfa (%)	Revolve (%)	*p*
No.	168 (62.9)	44 (16.48)	55 (20.6)	
Mean age ± SD, yr	54.77 ± 9.51	51.93 ± 9.80	51.44 ± 8.30	0.031*†
Race				
White	143 (85.12)	40 (90.91)	48 (87.27)	0.51‡
African American	8 (4.76)	0 (0.00)	2 (3.64)	
Asian	6 (3.57)	0 (0.00)	1 (1.82)	
Other	4 (2.38)	2 (4.55)	0 (0.00)	
Undisclosed	7 (4.17)	2 (4.55)	4 (7.27)	
Mean BMI ± SD, kg/m^2	26.19 ± 4.92	28.60 ± 6.16	27.93 ± 5.23	0.007*†
Comorbidities				
HTN	11 (6.55)	5 (11.36)	8 (14.55)	0.16‡
DM	6 (3.57)	0 (0.08)	1 (1.82)	0.38‡
CAD	0 (0.00)	0 (0.00)	0 (0.00)	—
PAD	0 (0.00)	0 (0.00)	0 (0.00)	—
Previous breast reconstructive surgery	166 (98.81)	44 (100.00)	55 (100.00)	0.55‡
Breast reconstruction				0.65‡
Autologous	128 (76.19)	35 (79.55)	45 (81.82)	
Implant	28 (16.67)	5 (11.36)	5 (9.09)	
Autologous and implant	12 (7.14)	4 (9.09)	5 (9.09)	
History of smoking	25 (14.88)	8 (18.18)	13 (23.64)	0.32‡
Fat grafting				
Unilateral	99 (58.9)	22 (50.00)	27 (49.1)	0.32‡
Bilateral	69 (41.1)	22 (50.00)	28 (50.9)	0.32‡
Graft volume, cc				
Median	120	70	160	
IQR	60–163.75	50–97.5	100–280	<0.0001†§
Adjuvant radiotherapy	85 (50.6)	29 (65.9)	31 (56.4)	0.181‡

BMI, body mass index; HTN, hypertension; DM, diabetes mellitus; CAD, coronary artery disease; PAD, peripheral artery disease; IQR, interquartile range.
*One-way analysis of variance.
†Statistically significant.
‡χ^2 test.
§Kruskal-Wallis test.

diabetes mellitus, coronary artery disease, and peripheral arterial disease), and smoking history (Table 1). Patients that underwent the centrifuge technique were marginally older in age (centrifugation, 54.8 years; Telfa, 51.9 years; and Revolve, 51.4 years; $p = 0.031$), whereas individuals that had grafting by means of Telfa had a significantly higher mean body mass index (centrifugation, 26.2 kg/m^2; Telfa, 28.6 kg/m^2; and Revolve, 27.9 kg/m^2; $p = 0.007$). Almost all of the patients (99.3 percent) had a previous breast operation before grafting, and the proportions of the types of reconstruction (i.e., autologous, implant, and autologous and implant) were comparable between groups ($p = 0.55$), with autologous being the most common. The remaining two patients who did not undergo breast reconstruction had autologous fat grafting to their mastectomy site for reconstruction. There were similar numbers of unilateral and bilateral fat transfers performed in each of the grafting categories ($p = 0.32$). The total volume of fat grafted was significantly different between groups ($p < 0.0001$). The highest volume of fat was transferred using the Revolve technique (160 cc), compared with centrifugation (120 cc) or Telfa (70 cc). Moreover, timing of adjuvant radiotherapy to breast fat grafting was significantly different between groups ($p = 0.042$), with Telfa having the shortest time interval (2.2 years) compared with centrifugation (5.6 years) and Revolve (3.2 years).

When evaluating postoperative complications, the incidence of oil cyst formation was highest in the centrifugation group before fat grafting (12.5 percent) compared with Telfa (0 percent) or Revolve (7.3 percent) ($p = 0.034$). Similarly, other complications were significantly higher in the centrifuge (13.7 percent) processing group compared with Telfa (2.3 percent) or Revolve (0.0 percent) ($p = 0.002$). When combining all complications (other complications plus oil cyst formation plus fat necrosis), centrifuge processing had more adverse events (25.6 percent) compared with Telfa (4.5 percent) or Revolve (10.9 percent) ($p = 0.001$) (Fig. 1). Larger volumes of transferred fat were significantly correlated with a higher incidence of all complications ($p = 0.007$) (Table 2).

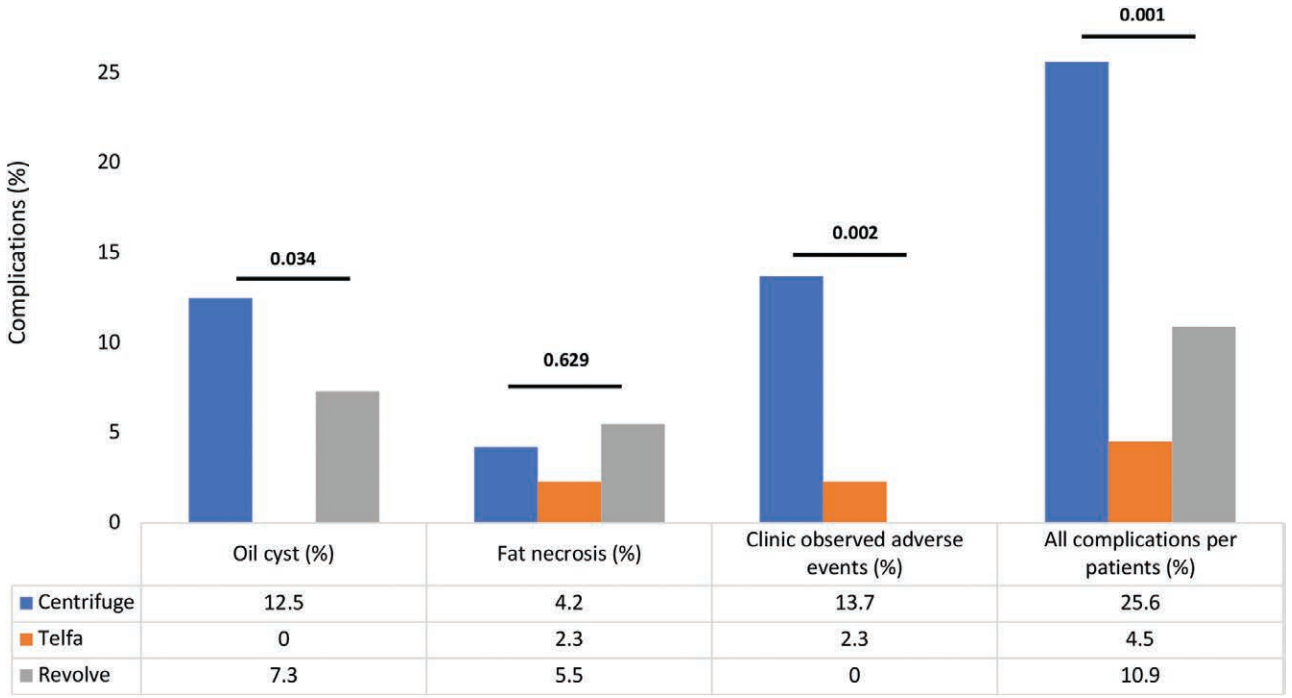


Fig. 1. Perioperative complications of patients undergoing the three techniques of fat processing before grafting.

Table 2. Comparison of Total Mean Fat Graft Volumes in Patients Who Developed Postoperative Complications versus No Complications

	Fat Graft Volume		
Complication Status	Oil Cyst (cc)	Fat Necrosis (cc)	All Complications per Patient (cc)
Complication sustained			
Mean	120	135	135
IQR	65–245	70–240	85–240
No complication sustained			
Mean	110	110	100
IQR	60–164.25	60–168.75	60–160
p	0.272	0.201	0.007*

IQR, interquartile range.
*Mann-Whitney *U* test; statistically significant difference.

Table 3. Number of Repeated Injections Needed following Each Grafting Technique

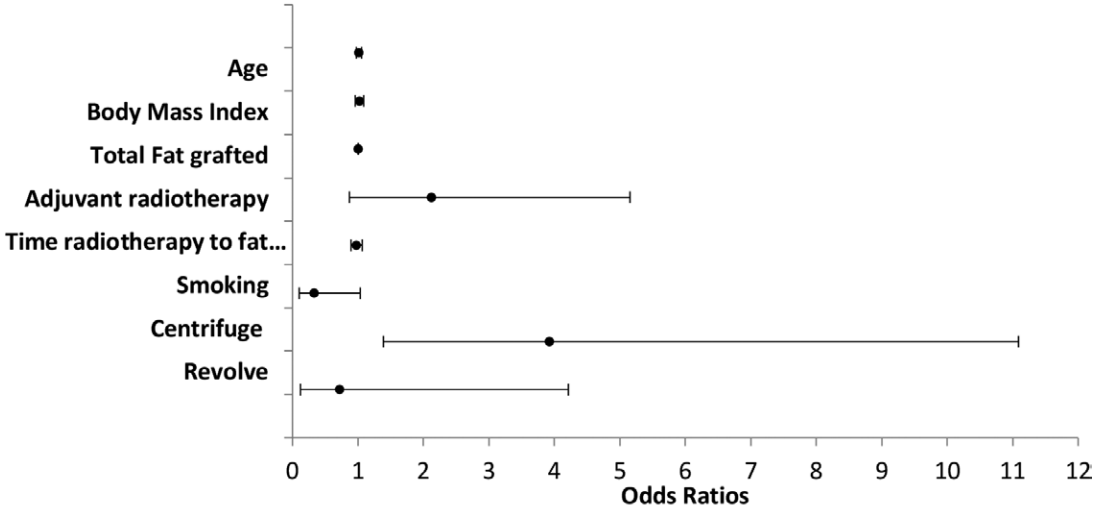
	No. Repeated Injections				
Graft Technique	One (%)	Two (%)	Three (%)	Total Injections (%)	*p*
Centrifugation	22 (13.1)	6 (3.6)	5 (3.0)	33 (19.6)	
Telfa	4 (9.1)	1 (2.3)	0 (0.0)	5 (11.4)	0.029
Revolve	3 (5.5)	0 (0.0)	0 (0.0)	3 (5.5)	

Primary autologous fat transfer using centrifugation was significantly associated with a higher number of procedures to obtain optimal aesthetic results (19.6 percent; $p = 0.029$). Alternatively, Revolve was associated with the least number of procedures for repeated fat grafting (5.5 percent). More specifically, only 5.5 percent of patients required one repeated fat grafting procedure following initial surgery. Patients who underwent the centrifugation technique had significantly more incidences of multiple return visits to the operating room for fat grafting, with 3.6 percent and 3.0 percent of patients requiring an additional two and three procedures, respectively (Table 3).

Multivariate analysis was performed to identify predictors of overall complications following various fat grafting techniques. A higher total graft volume regardless of technique involved (OR, 1.004; $p = 0.002$), and the technique of centrifugation (OR, 3.925; $p = 0.010$), increased overall complication rates (Fig. 2). Adjuvant radiotherapy and timing of radiotherapy had no bearing on overall rate of complication following fat grafting.

DISCUSSION

Despite the increasingly widespread use of fat transfer in plastic surgery, there is no superior method of fat processing technique accepted in the literature. A study by Kling et al. in 2013 showed that of plastic surgeons that performed fat grafting, 45 percent used gravity separation, 34 percent used



Independent Variable	Odds Ratio	95% Confidence Interval	*p*-value
Age	1.015	0.976 – 1.055	0.471
Body Mass Index	1.021	0.958 – 1.088	0.519
Total Fat grafted	1.004	1.002 – 1.007	0.002
Adjuvant radiotherapy	2.117	0.870 – 5.155	0.098
Time radiotherapy to fat grafting	0.976	0.894 – 1.065	0.578
Smoking	0.326	0.103 – 1.035	0.057
Centrifuge	3.925	1.389 – 11.089	0.010
Revolve	0.716	0.122 – 4.214	0.712

Fig. 2. Multivariate analysis: impact of independent variables on overall complications per patient.

centrifugation, 11 percent used gauze/Telfa rolling, and 3 percent did not process the fat.[11]

The principal underlying fat processing before injection is the widely held understanding that the maintenance of adipocytes in their physiologic state away from inflammatory contaminants such as blood, cell debris, and free oil will promote retention following transfer.[12] Higher concentrations of grafted fat in place of fluid or oil further encourage graft survival.[10] Failure of the above results in complications, with the most common being oil cyst formation and fat necrosis.[12] In this series, 9 percent of patients developed oil cyst and approximately 4 percent developed fat necrosis. The reported incidence of oil cyst and fat necrosis in the literature is between 3 and 17 percent,[13,14] coinciding with our clinical findings. Our study did not show a direct relationship between fat graft volume and oil cyst formation or fat necrosis. Other studies showed that fat necrosis and oil cyst formation were more prevalent in larger volume grafts.[15] It has been postulated that adipocytes located in the center of these constructs do not receive sufficient nutrient support from the surrounding tissues, which eventually results in liquefaction and resorption.[16] Despite our study not showing direct relationships between graft volume and oil cyst formation or fat necrosis, there was a higher incidence when combining all complications, suggesting that high-volume grafting could potentially harbor greater risks.

Fat processing technique choice may depend on volume of fat required, availability of equipment, and the surgeon's preference. Comparisons among the three techniques illustrate centrifugation having a significantly higher likelihood of postoperative oil cyst formation (12.5 percent), other complications (13.7 percent), and overall complication rate (25.6 percent) compared with both Telfa and Revolve. Previous studies have demonstrated no significant difference in the published literature with regard to donor site, tumescent fluid, or cannula size. Also, they found benefit from centrifugation relative to sedimentation.[17] Animal studies examining processing techniques of lipoaspirates by centrifugation resulted

in smaller graft size, reduced cell proliferation and nucleated adipocytes, and poorer architectural integrity.[18] Moreover, fat grafts that are centrifuged contain the least amount of contaminants but the greatest number of nonviable adipocytes. This could explain the significantly higher complication rates associated with the centrifugation technique, which also required the highest number of repeated grafting procedures following the initial procedure. Khater et al.,[19] through immunohistochemical staining, expounded on the concept of preadipocytes, which are immature cells with higher tolerance to ischemia and a greater ability to revascularize quickly following transfer.[20] The group showed that without using centrifugation in processing, more preadipocytes could be detected, thereby enhancing subsequent tissue survival and successful graft take.

Telfa appeared to have the best overall safety profile, including rates of oil cyst (0.0 percent), fat necrosis (2.3 percent), and other complications (2.3 percent). Prior clinical studies showed greater adipose-derived stem cell yields in fat processing following Telfa compared with centrifugation.[15] This is largely attributed to centrifugation being more disruptive to cell viability compared with Telfa.[15,21] Recent in vivo models illustrate Telfa-processed lipoaspirates having greater number of functional adipocytes and 10-week graft survival percentage compared with centrifugation. Telfa-processed lipoaspirates maintained greater secretion of vascular endothelial growth factor, platelet-derived growth factor, and overall vascularity compared with centrifugation and unprocessed fat. As a result, Telfa-processed lipoaspirates contain more functional adipocytes, leading to enhanced graft survival and decreased fat necrosis.[22] The low complication rate demonstrated in our study suggests the added benefits of the Telfa technique inducing lesser trauma to adipocytes within the lipoaspirates. Clinically, Telfa processing is more cost-effective[23]; however, it is extremely labor- and time-intensive. When used for large-volume fat grafting, there is significant loss of the fat grafts and volume. The Telfa technique is not a closed system of processing, exposing the fat grafts to the environment, and could potentially introduce issues with sterility.

The Revolve technique appears to have a safe complication profile compared with the Telfa and centrifuge processing techniques. The Revolve system resulted in a significant reduction in number of repeated injections following the initial graft procedure (5.5 percent), whereas centrifuge processing was associated with the highest number of repeated injections (19.6 percent), followed by Telfa (11.4 percent). Ansorge et al.[10] compared the in vitro and in vivo fat retention from lipoaspirate processed by Revolve, decanting, and centrifugation following liposuction from 10 patients. Results demonstrated significantly less blood cell debris, a higher percentage of adipose tissue, and a lower percentage of free oil in preinjected fat compared with the other two methods. Also, volume retention of transplanted fat was the greatest using the Revolve system, which demonstrated the lowest standard deviation in percentage, thereby reflecting the higher relative predictability of graft survival compared with the methods of decanting and centrifugation.[3] Our data demonstrate Revolve being associated with the largest volume of fat grafted. This coincides with previous literature that shows a significant increase in the rate of fat transfer using the Revolve system compared with the Coleman technique. Cost analysis comparing the Revolve and Coleman techniques suggest that in cases of planned fat transfer greater than 75 cc, Revolve is more economically beneficial secondary to decreased operating room costs.[24] In our study, patients who had fat grafting with the Revolve system were least likely to require repeated grafting and had larger initial fat grafting volume.

Our study has multiple limitations. Inclusion criteria included a minimum of one documented postoperative clinic visit. However, a majority of the cohort had a greater than 1-year follow-up. We assume in our study patients with clinically significant fat necrosis, oil cyst formation, and breast asymmetry would return to the office for evaluation. However, patients may be seen at outside hospitals for second opinions following their original operation. Furthermore, because operative workload was shared by different surgeons within the division, differing techniques of harvest or injection could have contributed to the observed complications despite us having controlled for the techniques of fat processing. Limitations in the details of each operative note prevented us from effectively taking into account the variations in techniques used in each case of autologous fat transfer. Moreover, the choice of fat processing technique was based on each surgeon's preference and resource availability. The volume of fat to be harvested had no bearing on fat processing technique. Despite our retrospective study findings, further research including prospective, randomized, and in vivo studies will be required to identify the optimal method of fat processing.

CONCLUSIONS

A wide variety of fat processing techniques continue to be used by plastic surgeons to enhance breast reconstruction outcomes. Centrifuge fat processing harbored the highest rates of postoperative complications, and Telfa exhibited the best safety profile. However, Telfa processing represents a labor-intensive technique that may be less feasible for large-volume fat grafting procedures. The Revolve system offers an alternative reliable method with an intermediate complication profile and least need for repeated fat grafting. Future research should aim at performing prospective, randomized studies to identify the optimal method of fat processing.

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