Breast Augmentation Using Preexpansion and Autologous Fat Transplantation: A Clinical Radiographic Study

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Background: Despite the increased popularity of fat grafting of the breasts, there remain unanswered questions. There is currently no standard for technique or data regarding long-term volume maintenance with this procedure. Because of the sensitive nature of breast tissue, there is a need for radiographic evaluation, focusing on volume maintenance and on tissue viability. This study was designed to quantify the long-term volume maintenance of mature adipocyte fat grafting for breast augmentation using recipient-site preexpansion.

Methods: This is a prospective examination of 25 patients in 46 breasts treated with fat grafting for breast augmentation from 2007 to 2009. Indications included micromastia, postexplantation deformity, tuberous breast deformity, and Poland syndrome. Preexpansion using the BRAVA device was used in all patients. Fat was processed using low–*g*-force centrifugation. Patients had preoperative and 6-month postoperative three-dimensional volumetric imaging and/or magnetic resonance imaging to quantify breast volume.

Results: All women had a significant increase in breast volume (range, 60 to 200 percent) at 6 months, as determined by magnetic resonance imaging ($n = 12$), and all had breasts that were soft and natural in appearance and feel. Magnetic resonance imaging examinations postoperatively revealed no new oil cysts or breast masses.

Conclusions: Preexpansion of the breast allows for megavolume (>300 cc) grafting with reproducible, long-lasting results that can be achieved in less than 2 hours. These data can serve as a benchmark with which to evaluate the safety and efficacy of other core technology strategies in fat grafting. The authors believe preexpansion is useful for successful megavolume fat grafting to the breast. (*Plast. Reconstr. Surg.* 127: 2441, 2011.)

Recent evidence from a variety of independent investigators[1,2] suggests that fat grafting to the breast is a procedure that can yield natural, long-term results. Because of unknown potential long-term effects of fat transplantation into the breast, careful study is warranted. In January of 2009, the American Society of Plastic Surgeons revised their position on fat grafting to the breasts, and cautioned that "results of fat transfer remain dependent on a surgeon's technique and expertise."[3] The use of preexpansion of the breast recipient site before grafting has been suggested to yield impressive long-term volume maintenance[4]; however, there are currently few to no published data with which to evaluate this on an objective basis. The purpose of the present study was to quantify the clinical results of nonsurgical preexpansion and autologous fat grafting in breast augmentation.

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PATIENTS AND METHODS

From 2007 to 2009, 25 patients (46 breasts in total) desiring breast augmentation were selected to undergo autologous fat grafting. Patients ranged in age from 21 to 60 years. Some exhibited severe

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unilateral asymmetry caused by Poland syndrome or other growth-related asymmetries. Patients were initially photographed and underwent three-dimensional breast imaging and/or breast magnetic resonance imaging using intravenous gadolinium contrast in a 4-T breast coil (Department of Radiology and Breast Imaging, Boston University Medical Center, Boston, Mass.).

Use of BRAVA Preexpansion before Fat Grafting

Under institutional review board approval, patients underwent preoperative nonsurgical breast expansion for a period of 3 weeks by means of an external expansion device (BRAVA, LLC, Miami, Fla.). The device consisted of a rigid plastic dome with silicone gel cushioning at the base and with tubing connected to a negative-pressure pump (Fig. 1). Expansion programs were individualized for each patient based on lifestyle analysis and psychological compliance testing. Patients who could not comply with their programs had their target dates for surgery extended to achieve proper preexpansion.

Patients were followed closely during preoperative expansion with serial inpatient examinations and three-dimensional breast imaging. They were encouraged to overexpand according to their desired final breast volume, following the "1-2-3 rule" (Fig. 2).

Immediately following preexpansion, and after the patients gave their written and verbal informed consent, patients underwent autologous fat transplantation. No high-speed centrifugation was used to process fat in this patient series. Fat was allowed to separate from unwanted crystalloid and was then centrifuged at low *g* forces (20 to 40 *g*). A range of 220 to 550 cc of fat per session was injected into each breast.

Fig. 1. The BRAVA external tissue expander worn by a patient just before the fat grafting procedure. Note that the expanded breast tissue is almost in contact with the domes. Fogging of the domes because of evaporative water loss is normal.

In the first 24 hours after grafting, there was no external compression or negative pressure used. Beginning at 24 to 48 hours after grafting, patients were placed back into BRAVA domes, which were placed under low battery pump suction. Patients wore their external expansion devices for 2 to 4 weeks postoperatively and were followed up at regular intervals. Patients underwent a second postoperative magnetic resonance imaging examination 6 months after their fat grafting session to evaluate tissue viability, volume maintenance, and parenchymal abnormalities.

Quantitative Results: Objective Volume Measurements

Patients who completed both preoperative and 6-month postoperative breast magnetic resonance imaging ($n = 12$) provided volumetric data sets that were subjected to analysis. All magnetic resonance imaging scans were read and all quantitative magnetic resonance imaging analyses were performed independently by the same radiologist. The radiologist responsible for all magnetic resonance imaging readings was employed at an academic medical center that was chosen on the basis of magnetic resonance imaging cost in the primary author's (D.A.D.V.) geographic area. Neither author was affiliated with this academic medical center. Baseline preexpansion volumes and 6-month postoperative volumes were measured using the semiautomated computer-generated method of volume measurement, which is considered to be the most accurate method of quantifying breast volumes by magnetic resonance imaging.[5]

The average preoperative volume of the breasts measured by magnetic resonance imaging in this study was 284 cc. The average 6-month postoperative breast volume was 557 cc, for an average increase in volume of 272 cc. On a percentage increase basis, this represented a 106 percent increase, or a two-fold increase in breast volume on average. Because different clinical goals existed in each patient, there was a range of volume increases at 6 months after grafting (107 to 345 cc). Subjecting the data to paired, open-ended *t* testing, the difference between the preoperative

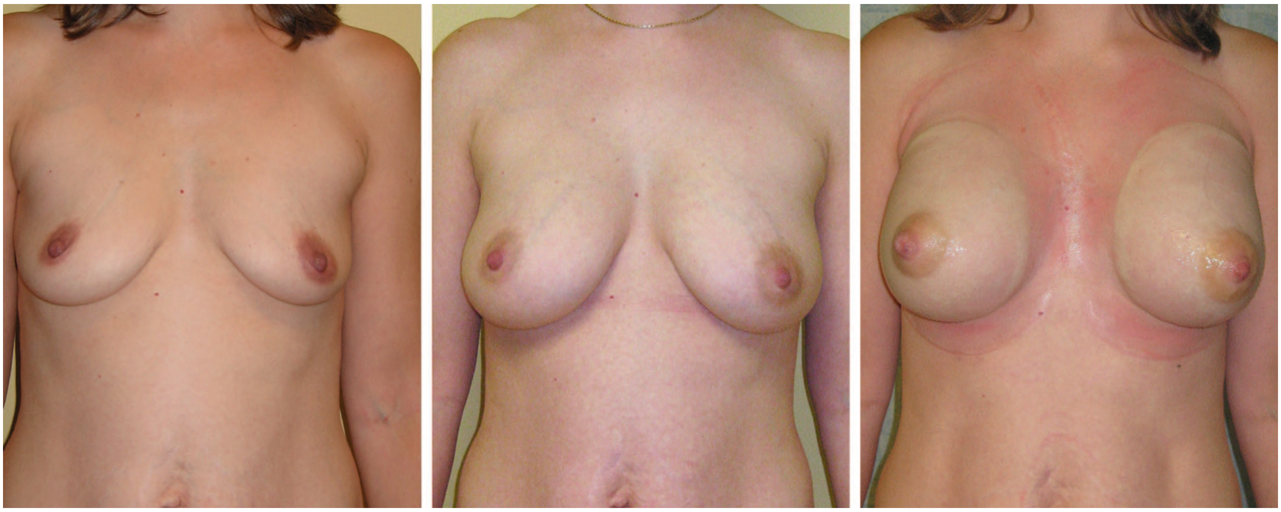

Fig. 2. The "1-2-3 rule" states that if you are a 1 and you want to be a 2, you must expand to a 3. A patient (*left*) who wants to double final volume at 6 months (*center*) must triple in expansion (*right*). Patients should not expand to their desired breast volume but should hyperexpand and surpass their desired size to achieve optimal results.

and 6-month postoperative results was statistically significant, with a value of $p = 0.0000003$. In any given patient, volume increases were similar, and the variance between increases in breast volume was small, suggesting reliability of the technique in terms of obtaining symmetry. The raw data set is provided in Table 1.

The average procedure time was 2 hours. Initially, the procedures took over 2 hours; however, after an initial learning curve, procedures took

Table 1. Raw Volumetric Data Sets from Quantitative Magnetic Resonance Imaging Scans in 12 Patients Showing Methodology of Preexpansion and 6-Month Postoperative Breast Volumes*

Clinical Data			Volumetric Data						
Patient	Age (yr)	Indication for Surgery	Breast	Before	After	Change	Increase (%)	Graft	Yield (%)
1†	34	Tuberous breasts	Left	383	684	301	79	600	50
			Right	385	686	301	78	600	50
2†	29	Tuberous breasts	Left	240	585	345	144	600	58
			Right	289	611	322	111	600	54
3	35	Postpartum deflation	Left	267	518	251	94	380	66
			Right	251	479	228	91	380	60
4	21	Severe breast asymmetry	Left	107	337	230	215	220	105
5	26	Micromastia	Left	156	463	307	197	420	73
			Right	166	476	310	187	420	74
6	30	Postpartum deflation	Left	351	565	214	61	360	59
			Right	338	552	214	63	360	59
7	42	Poland syndrome	Right	332	720	388	117	450	86
8	28	Micromastia	Left	350	638	288	82	430	67
			Right	396	698	302	76	430	70
9	25	Micromastia	Left	333	586	253	76	450	56
			Right	300	553	253	84	450	56
10	41	Micromastia	Left	97	204	107	110	230	47
			Right	104	227	123	118	230	53
11	60	Explantation of prostheses	Left	225	428	203	90	380	53
			Right	261	498	237	91	380	62
12	45	Postpartum deflation	Left	498	927	429	86	550	78
			Right	427	808	381	89	550	69
Average‡				284	557	272	106	430	64
SD									13

*Cases with only one data set represent unilateral breast augmentation because of severe developmental asymmetry.
†Two sessions of 300 cc each.
‡t test, $p = 0.0000003$.

under 2 hours with the aid of one surgical assistant. There were no complications, including hematoma, seromas, or infections.

Qualitative Results: Radiologic Magnetic Resonance Imaging Analysis

All magnetic resonance imaging data were read by the same radiologist at the same institution using the same breast coil. In none of the cases was there evidence of newly occurring oil cysts, fat necrosis, or breast masses seen in the 6-month postoperative magnetic resonance imaging scans. The tissue that contributed to the over two-fold increase in breast volume consisted entirely of tissue that, by weighted magnetic resonance imaging, represented viable fat (Fig. 3).

CASE REPORTS

Case 1

A 35-year-old G2P2 woman desired increased breast size. She had previously been happy with her breast volume but after several pregnancies, she lost some volume and felt her breasts were deflated. She did not want to have breast augmentation with prosthetic implants and desired a fuller appearance. She demonstrated relatively symmetric, well-developed soft breasts with no constrictions. She was initially expanded with a BRAVA handheld pump, for 10 hours per day for 3 weeks (Fig. 4). Because she had already experienced expansion through lactation, her external expansion proceeded well. After 3 weeks of expansion, she underwent 380 cc of fat injected into each breast, harvested during liposuction of the thighs. At 6 months after grafting, her result was stable (Fig. 5).

Case 2

A 28-year-old nulliparous woman desired increased breast size. She was pleased with the overall shape. She demonstrated relatively symmetric, well-developed, soft breasts with no constrictions or severe density. She did not desire breast implants. She was initially expanded with a BRAVA handheld pump, for 10 hours per day for 3 weeks. She was a very compliant patient, and her expansion proceeded well over serial office visits. After 3 weeks of expansion, she underwent 450 cc of fat injected into each breast, harvested during liposuction of the thighs. At 6 months after grafting, her result was stable (Fig. 6).

Case 3

A 32-year-old woman with tuberous breast deformity desired increased breast size and improved shape. She demonstrated constricted inframammary folds and herniation of breast parenchyma subjacent to the nipple-areola complex. She did not desire breast implants. She was initially expanded with a BRAVA Sport Pump, a low-pressure battery-operated pump, for 3 weeks before her first fat grafting procedure, during which 300 cc of processed fat was injected into each breast. She also underwent periareolar reduction. It was felt that the low negative pressure created by the Sport Pump was not ideal and that additional expansion could have been achieved by using a handheld pump with a higher vacuum pressure.

After 4 months, she underwent a second session of BRAVA preexpansion, using a hand pump, and had a second round of grafting with 300 cc of additional fat per breast. Constrictions at the inframammary fold were addressed by three-dimensional percutaneous mesh release using a 14-gauge needle immediately after fat grafting (Fig. 7). Her results by photography and by magnetic resonance imaging before expansion and 8 months after her second procedure demonstrate a significant increase in volume and improvement in breast aesthetics (Figs. 8 and 9).

DISCUSSION

After Illouz first introduced liposuction as a means of reducing unwanted fat,[6] adipocyte grafting to the breast was briefly described in the literature.[7,8] However, this had largely been placed on "standby" for the past 20 years. It was not until an accumulation of case reports, paper presentations, and patient series began appearing by independent investigators[9,10] that the concept of fat grafting for breast augmentation was revisited, culminating in the American Society of Plastic Surgeons Breast Fat Grafting Task Force, who revised the position of the American Society of Plastic Surgeons in January of 2009.

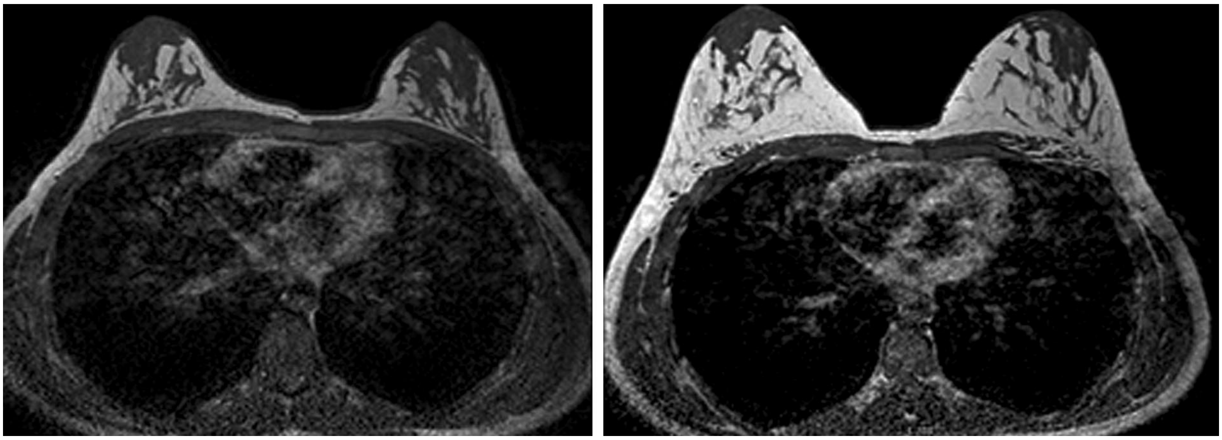

Fig. 3. Representative magnetic resonance imaging scans from the series. Tissue contributing to increased volume is consistent with viable fat. There are no cysts, masses, or fat necrosis.

Fig. 4. Case 1. The patient before (*left*) and 3 weeks after BRAVA expansion, immediately before fat grafting (*right*). Note that the volumetric increase is over two times that of the preexpansion state; 380 cc of fat was injected into each breast.

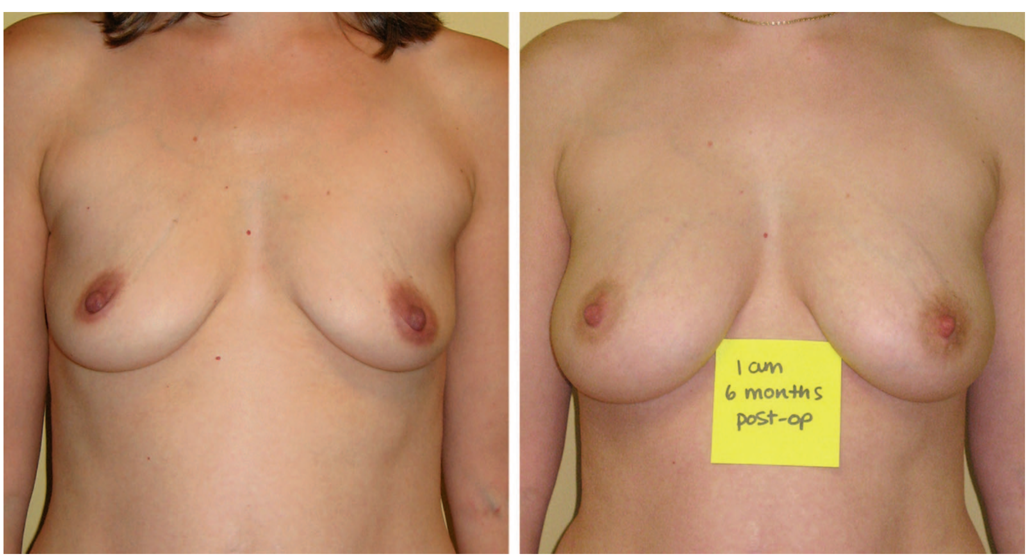

Fig. 5. Case 1. The patient before expansion (*left*) and 6 months after fat grafting (*right*). Note that the volumetric increase is nearly two times that of the preexpansion state. Although there is some mild ptosis, the breasts appear soft and natural, with preferential fill of the lower pole.

We define megavolume fat grafting for breast augmentation as the transplantation of over 300 cc of fat processed at 20 to 40 *g* for volume for core tissue projection replacement. Because there is a wide degree of fat processing, ranging from simple decanting (1 *g*) to hyperconcentrated fat (3000 rpm, or 1300 *g*), the volume of actual graft varies depending on the concentration method used.

Based on experience with diverse breast types, it was observed that the degree of physical expansion varied not only with *patient compliance* wearing the expansion device but also with the *mechanical compliance* of the recipient site. Factoring out the degree of adherence to the expansion program as a whole, patients with dense nulliparous breasts did not expand as well as multiparous breasts in our patient series. Constricted breasts expanded well but required ancillary procedures such as nipple-areola reductions, percutaneous release of constriction bands to lower the inframammary folds, or an additional grafting session to reshape the breasts. With reference to breast augmenta-

Fig. 6. Case 2. A nulliparous patient with soft breasts preoperatively (*left*) and 6 months postoperatively (*right*). Even in patients in whom liposuction alone would not likely be entertained, it is often possible to obtain a sufficient amount of fat. Expansion is easier in patients with soft breasts than in patients with dense breasts.

Fig. 7. Case 3. Three-dimensional mesh release technique. Immediately after fat grafting, injected fat provides an internal traction effect to help identify specific areas of parenchymal tethering and ligamentous bands. After inserting a 14-gauge needle into multiple sites and releasing the constriction bands, the irregularity is released and the fat immediately fills the space created, changing the shape to a more aesthetic result.

tion, we propose in Table 2 a hierarchy of preoperative breast morphologies that may assist surgeons in predicting for their patients the number of treatment sessions required for the desired aesthetic result.

The study period of 6 months for a postoperative magnetic resonance imaging scan was decided on based on the following logic. It is currently well accepted that grafted dermis survives by diffusion and becomes vascularized by neoangiogenesis, usually within 7 to 14 days. Once this occurs, the skin graft usually survives indefinitely. Although the exact same process cannot be assumed in fat grafting, this "diffusion angiogenesis" theory of fat graft survival is currently the most popular theory of how fat cells survive transplantation. Edema does not normally persist in human tissue 6 months following fat grafting. Fat necrosis or cysts could potentially contribute to long-term volume maintenance, but these were not seen by magnetic resonance imaging in this study.

There is clinical evidence for successful volume maintenance in breast augmentation using fat processed at high *g* forces (1300 *g*) without the use of preoperative expansion.[11] Although possible, effective volume augmentation in the unexpanded breast may be limited by high, nonphysiologic interstitial pressures reached at the recipient site and the resultant smaller volumes of fat that can be injected in one session. The same evidence for successful small graft volume (18 to 34 cc) has been reported in breast reconstruction where ancillary fat grafting has been used successfully for breast reconstruction of border-zone contour irregularities.[12] Smaller volumes of graft compared with the recipient-site volumes potentially result in maintenance of a physiologic interstitial pressure environment and a favorable surface-to-volume ratio of graft to recipient, improving oxygen diffusion in the early days after grafting. Be-

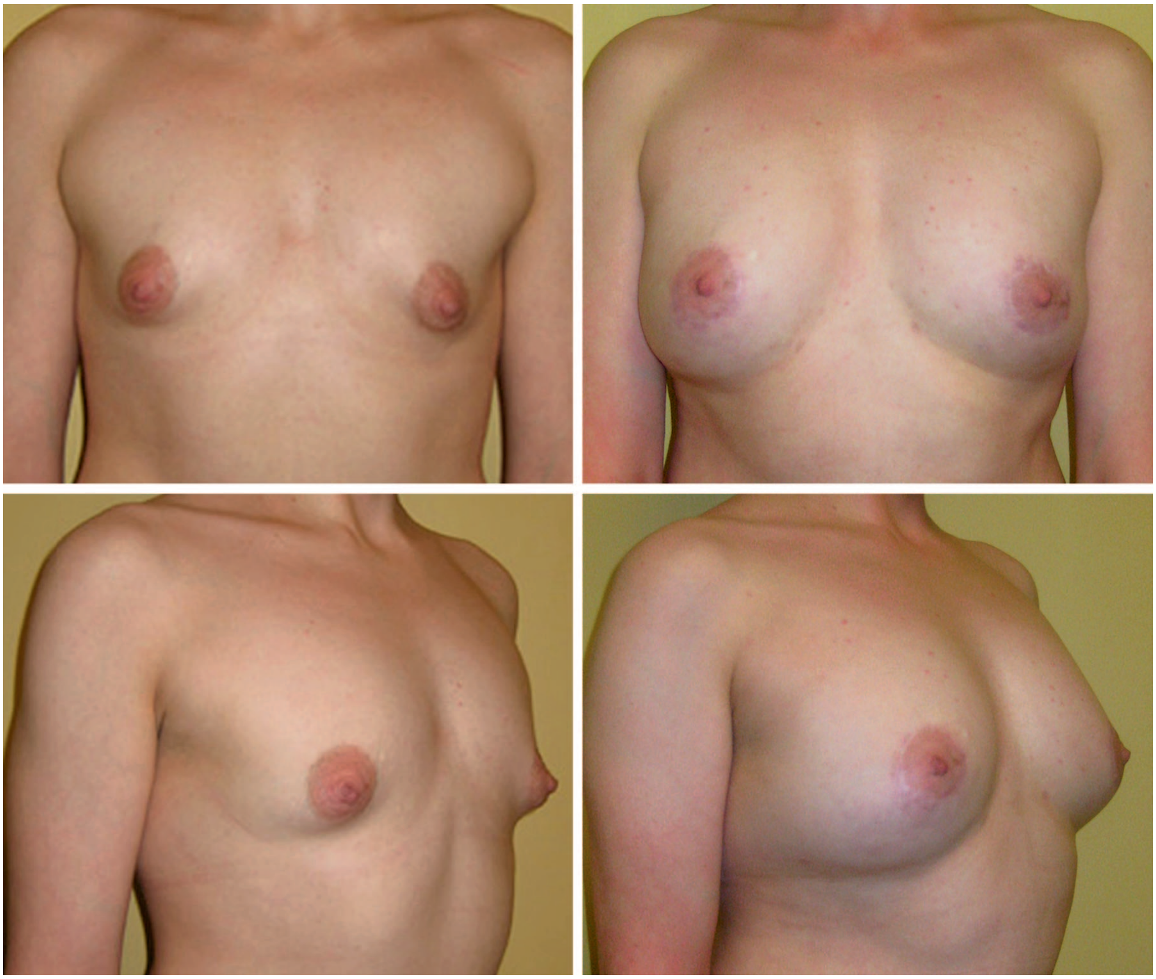

Fig. 8. Case 3. (*Left*) Anterior and right anterior oblique preoperative views of a patient with severe constricted breasts before expansion and (*right*) 7 months after a second session of fat grafting. Constricted or tuberous breasts can be augmented and reshaped with significant lowering of the inframammary fold through percutaneous three-dimensional mesh release. Such breasts will often require two sessions to fill the volume needed and to change breast shape. Note the significant lowering of the inframammary fold and the increased inframammary fold–to–nipple-areola complex distance postoperatively.

cause the injected adipocyte plays a dual role of autologous graft in need of oxygen and an internal expander, there is more demand on hyperconcentrating fat in the unexpanded breast. The more graft that is implanted, the higher the potential interstitial pressure. There is a lower mechanical/pressure limit to graft volume in the unexpanded breast scenario.

Not all patients underwent breast magnetic resonance imaging. Because this study was self-funded, some patients desired the procedure, underwent the procedure, but were not able to pay for the follow-up magnetic resonance imaging. There was no difference in patient selection, surgical technique, or clinical outcomes in patients who did or did not undergo magnetic resonance imaging. The magnetic resonance imaging data set was selected for analysis in favor of combining three-dimensional volumetric imaging data and magnetic resonance imaging data, because magnetic resonance imaging volumetric data are the most accurate and objective data available. Although only 50 percent of patients underwent both preexpansion and 6-month postoperative magnetic resonance imaging, the data set was large enough to objectively demonstrate a statistically significant volume increase at 6 months.

Comparing preexpanded breast augmentation with fat versus nonpreexpanded breast augmentation with fat, BRAVA-preexpanded breasts have the mechanical/pressure advantage of having increased parenchymal space, reducing the

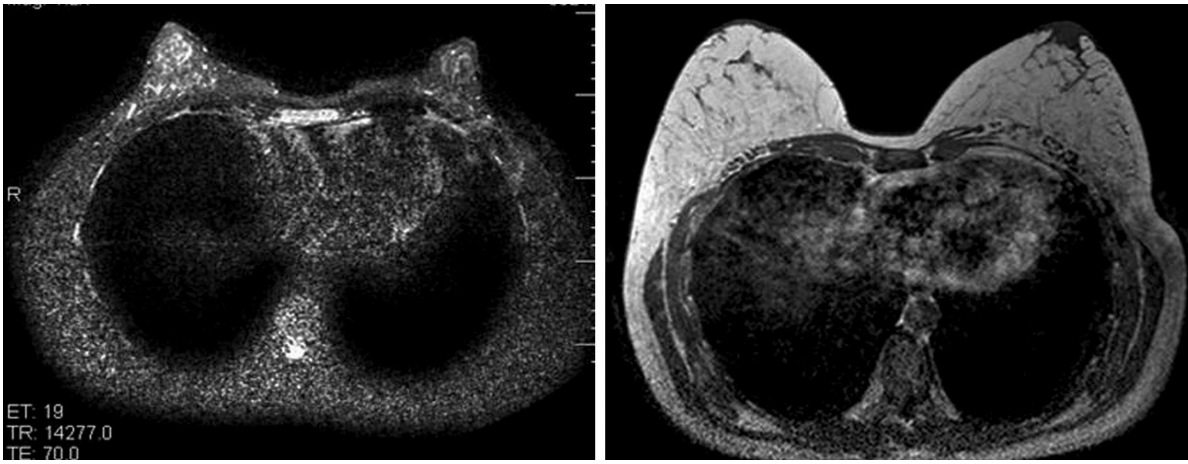

Fig. 9. Case 3. (*Left*) Preexpansion magnetic resonance imaging scan of the patient. (*Right*) Scan obtained 6 months after the second fat grafting procedure. An increase of 300 cc was measured.

Table 2. Preexpansion Classification Based on Breast Morphology

Type*	Description of Breasts	Grafting Sessions
I	Multiparous, soft	1
II	Nulliparous, dense	1–2
III	Constricted or tuberous	2–3

*Type number correlates with predicted number of grafting sessions required.

deleterious effect of graft crowding and interstitial hypertension. There is no requirement on the grafted cell to act as an "internal expander"; the graft simply "back-fills" the expanded parenchyma. Preexpansion of the breast recipient site eliminates the need for high-speed centrifugation and its potential disadvantages of longer procedure times and cellular damage.[13,14] In the expanded space, a larger amount of less concentrated fat can be more diffusely dispersed and potentially survives better, with fewer assistants processing the graft, resulting in patient-safe and surgeon-friendly procedure times.

In open wounds, micromechanical forces such as vacuum elicit tissue deformation forces that stretch individual cells, thereby promoting proliferation in the wound microenvironment. The application of micromechanical forces on cells has been demonstrated as a useful method with which to stimulate wound healing through the promotion of cell division, angiogenesis, and local elaboration of growth factors.[15,16] The deformational forces of the vacuum-assisted closure device are consistent with this mechanism of action, and are similar to the vacuum effects of external expansion to the breast that occur with use of the BRAVA device. Preexpansion to the breast may therefore be more than just "increasing space." Negative-pressure therapy to the breast may demonstrate similar effects of angiogenesis, cell division, and up-regulation of growth factors, which is currently an area of laboratory study for us. To summarize, there are several key differences between classic fat grafting to the unexpanded breast and fat grafting using preexpansion, which may account for the long-term stability of the results and the larger volumes of graft used in this series, outlined in Table 3.

One of the most misunderstood metrics in fat grafting is the use of "percentage yield" or "percentage graft survival." The concept of percentage yield represents a paradigm carry-over from two-dimensional skin grafting, which cannot be readily translated to fat. Unlike the two-dimensional surface areas of dermal grafts, which are placed over

Table 3. Classic Fat Grafting Compared with Preexpansion Technique for Breast Augmentation

	Classic Fat Grafting	Preexpanded Grafting
Expander	Injected adipocytes	BRAVA expander
Role of fat	Internal pressure expander	Back-fills expansion
Apparent interstitial pressure*	High	Lower
High-speed centrifugation	Dependent	Not necessary
Syringe size	3–5 cc	5–60 cc
Estimated operating time	4–6 hr	2 hr
No. of assistants	2–6	0–1
Recipient-site modulation	None	Micromechanical forces

*Assumed, not proven.

nondermal wounds and are easily measured, when fat is lipoaspirated with tumescent solution, there are an infinite number of different concentrations of fat relative to crystalloid that can be processed before grafting the recipient site, which is a three-dimensional matrix that consists of fat and other preadipocyte components. This makes fat yield much more challenging to measure or to compare among clinical series. Unless we standardize a process and quantify the cellular concentration of the donor graft, it is difficult to quantify clinically what percentage of fat survives grafting. Preexpansion is believed to be beneficial in fat grafting to the breast for five main reasons:

*B*igger overall parenchymal space, as demonstrated by photography
*R*educed interstitial pressure in the breast for a given volume of graft injected
*A*ugmentation of contour irregularities before grafting, so shape can be modified
*V*ariables such as high-speed centrifugation can be omitted for shorter operating room times
*A*ngiogenesis; postulated by micromechanical forces at the recipient site

The importance of immobilizing a split-thickness skin graft postoperatively is well recognized. Following grafting, the use of the BRAVA device may act as a splint. Conversely, a low negative pressure exerted postoperatively by the BRAVA bra may help immobilize the fat cells and aid in neovascularization to the graft. In any event, application of the domes in the postoperative period certainly protects the breasts from external trauma, which could inadvertently shift the graft and potentially disturb neovascularization.

This study set out to specifically examine the role of preexpansion in breast fat grafting and to describe a benchmark technique on which other techniques could be objectively compared. Because of fat's potential effect in causing cancer, the potential effects of aromatase, and the potential for fat to distort mammography, there are several difficult safety questions with no clear answer at this time. Going forward, both basic science and clinical studies will be required to specifically answer many of these questions.

CONCLUSIONS

The technique of preoperative breast expansion and autologous fat transplantation can be performed safely with reproducible significant volumetric results: a twofold increase on average performed in 2 hours or less. The range of breast volume increase is on the order of 60 to 200 percent of baseline breast volume in the series studied, for a nominal value of 250 cc of volume increase per breast on average. These results serve as a standard with which to objectively compare other techniques of fat grafting to the breast in the future. The absence of new breast masses or oil cysts by postoperative magnetic resonance imaging may be attributable in part to a more dilute fat volume injected. The optimal concentration of adipocytes used in breast augmentation may vary on a case-by-case basis, depending on the effective preparation and expansion of the recipient site. Megavolume fat grafting to the breast is technically feasible and time efficient, and yields predictable reproducible results when preexpansion to the recipient site is used optimally.

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