

Tissue-Engineered Breast Reconstruction with Brava-Assisted Fat Grafting: A 7-Year, 488-Patient, Multicenter Experience

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Background: The ability of autologous fat transfer to reconstruct an entire breast is not established. The authors harnessed the regenerative capabilities of external expansion and autologous fat transfer to completely reconstruct breasts.

Methods: The authors performed 1877 Brava plus autologous fat transfer procedures on 616 breasts in 488 women to reconstruct 99 lumpectomies, 87 immediate breast reconstructions, and 430 delayed total breast reconstructions. After 2 to 4 weeks of Brava expansion, which increased volume by 100 to 300 percent, the authors diffusely grafted the breasts with 100 to 400 ml (225 ml average) of 15 g-sedimented, manually harvested lipoaspirate. The procedure was repeated every 8 to 14 weeks until completion. The authors compared costs of this reconstruction with established deep inferior epigastric artery perforator/transverse rectus abdominis musculocutaneous flaps and implant procedures.

Results: Follow-up ranged from 6 months to 7 years (mean, 2.5 years), with 0.5 percent locoregional recurrence. Four hundred twenty-seven women completed the reconstruction, whereas 12.5 percent dropped out (2.5 percent medical, 10 percent personal reasons). Completion required 2.7 procedures for nonirradiated and 4.8 procedures for irradiated mastectomies. Patients recovered soft, natural appearing breasts with nearly normal sensation. Complications included five pneumothoraces and 20 ulcerative infections. Radiographically recognized benign palpable masses were observed in 12 percent of nonirradiated and 37 percent of irradiated breasts. The cost of Brava plus autologous fat transfer is 47 percent and 66 percent that of current reconstruction alternatives.

Conclusion: Brava plus autologous fat transfer is a minimally invasive, incisionless, safe, economic, and effective alternative for breast reconstruction. (*Plast. Reconstr. Surg.* 135: 643, 2015.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, IV.

Every year, more than 296,000 American women and 1.5 million women worldwide are diagnosed with breast cancer.^{1,2} After mastectomy, patients are given the option of undergoing reconstruction of their breasts with flaps or implants. Unfortunately, over 60 percent of American women elect to not undergo

reconstruction.³ They do not welcome invasive flap surgery and prefer to avoid prosthetic materials. Based on tissue-engineering principles, we developed a minimally invasive, patient-friendly alternative for women to regenerate their lost breast in situ without additional scars or incisions.⁴

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Tissue engineers build scaffolds and seed them with cells. Tissue-engineered organs are currently limited to thin constructs where cells survive by diffusion. A solid organ would require a three-dimensional capillary network connected to the host circulation for the inner cells to survive, something bioengineers have yet to build.⁵ Researchers have attempted to build scaffolds using titanium substrates, poly(L-glutamic acid), poly(L-lysine), and many more materials.⁶ However, incorporating into these scaffolds a functional vascular network remains the holy grail of tissue engineering.

Using Brava, a well-established vacuum-based external breast expander,^{7,8} we have harnessed the potential of mechanical forces to induce the body to generate its own three-dimensional vascularized scaffold that is well suited for fat grafting.⁷⁻¹³ This immense addition to our available techniques has enabled us to successfully perform the megavolume autologous fat transfer required to regenerate a breast mound.

Breast reconstruction with autologous fat transfer requires application of previously elucidated fundamentals.¹⁴ Brava expands the skin defect, generating the necessary skin envelope. Brava also expands the native stromal/vascular scaffold, resulting in a favorable recipient site where many more microribbons of fat can be diffusely inserted without coalescence and without significantly increasing interstitial fluid pressure. After expansion, using only needles, cannulas, and syringes, the surgeon seeds the generated scaffold with liposuctioned fat grafts to regenerate a breast mound.

There are several benefits to this procedure. The reconstruction is autologous, the surgery is minimally invasive (low risk of complications) and performed on an outpatient basis, the results are predictable, the patient regains sensation (a benefit unmatched by any alternatives), and the liposuctioned donor site is a cosmetic improvement with no additional scars. Armed with this tool, we took on many challenges extant in reconstructive breast surgery.

In a previous publication, we presented our experience using Brava-assisted megavolume autologous fat transfer for aesthetic breast augmentation.¹⁵ We hereby review our combined 7-year, 488-patient experience with Brava-assisted megavolume autologous fat transfer for breast reconstruction.

We recognize three subsets of patient presentations: delayed reconstruction, immediate reconstruction, and reconstruction of the irradiated

partial mastectomy defect. Using illustrative case examples, we present our results and describe our approach for each application.

DELAYED RECONSTRUCTION

Although it is possible to restore a breast mound after mastectomy using only autologous fat transfer, very little fat can be grafted per session, retention rates are low, and many grafting sessions are required to reconstruct only modest-sized breasts.¹⁶⁻¹⁹ The tight mastectomy defect limits the amount of fat that can be grafted per session, and the injected graft is limited in its ability to stretch the scar and create a skin envelope. However, the Brava-generated scaffold can now accept megavolume autologous fat transfer to yield a tissue-engineered mound.²⁰

IMMEDIATE RECONSTRUCTION

Immediate reconstruction solves two main limitations of megavolume autologous fat transfer¹⁴:

1. Graft-to-recipient interface: Fat grafting is usually a blind procedure. The surgeon does not see the graft as it is delivered under the skin, and is therefore never sure that the distribution is optimal. In the immediate reconstruction, in contrast, the exposed muscle is grafted under direct vision. The surgeon can see the microribbons of fat as they are injected between muscle fibers, therefore avoiding localized collections.
2. Interstitial fluid pressure limit: Because the fascia that normally restricts muscle expansion has been removed as part of the mastectomy, the muscle can incorporate a large volume of fat grafts and swell to many times its original volume without increasing interstitial fluid pressure.

Liposuction is performed in concurrence with the mastectomy. At the first grafting session, we were typically able to disperse 100 to 400 ml of fat in the submuscular, intramuscular, and intermuscular planes; the lateral thoracic fascia; and, if feasible, the base of the mastectomy flaps. Fat grafting adds approximately 30 minutes of surgery time, and the recovery from liposuction adds little morbidity. Although this first step generates only small breast mounds, it reduces the psychological trauma of the mastectomy. With the fullness mostly in the pectoralis, cephalic and medial, at least the “social breast” and cleavage are nicely restored. Four to 6 weeks after the mastectomy,

once the skin flaps have healed and adhered to the muscle, the patients start Brava expansion to further expand the recipient scaffold in preparation for the one to six additional grafting procedures that might be required to complete the reconstruction.

RECONSTRUCTION OF THE IRRADIATED LUMPECTOMY

Whenever possible, we recommend autologous fat transfer immediately after completion of irradiation. The grafted fat seems to have a soothing effect on the radiation-induced inflammation, and the interposed healthy grafts seems to reduce the amount of secondary fibrosis, causing the irradiated tissues to remain softer. In addition to serving as a volume filler, fat reduces fibrosis²¹ and has a regenerative effect on skin,²² nerves,²³ and blood vessels.²⁴

Most patients present weeks after radiation treatment with a volume deficiency and a distorting scar. They begin with 3 weeks of Brava use, which hastens wound healing by means of the vacuum-assisted wound closure effect,²⁵ loosens the scar contracture, expands the scaffold, and increases vascularity.^{7-13,25} The tissues are then fat grafted until the scar is under tension, which facilitates the previously described percutaneous aponeurotomy and lipofilling (PALF),²⁶ followed by additional autologous fat transfer.

PATIENTS AND METHODS

Between 2006 and 2013, we enrolled 488 women for tissue-engineered breast reconstruction with Brava-assisted autologous fat transfer in an institutional review board–approved study.²⁷ To enroll, they had to tolerate a 20-minute in-office Brava test. Exclusion criteria included smoking, prolonged bleeding, multiple previous liposuctions, planned future radiation treatment, and unrealistic expectations. This protocol requires women who are sufficiently patient and compliant to adhere to the required intensive Brava-wear schedule.

Brava is worn like a bra, mostly at home and at night. It should not cause any pain, but some patients find it uncomfortable and inconvenient.¹⁴ It can also cause rashes, itching, superficial blisters, and postinflammatory hyperpigmentation, especially in women of Asian or African descent. We consider these effects minimal compared with the morbidity and scarring inherent in the traditional reconstruction alternatives. Patients were asked to use the Brava device with the

high-vacuum cycling pump for 10 hours/day for 2 to 4 weeks. This pump cycles between -60 mmHg for 3 minutes to no pressure for 1 minute, taking advantage of the benefits of tissue expansion by cyclical forces.⁹ They were asked to continuously wear the Brava device over the weekends and for the last 24 to 48 hours before the operation. They were considered well prepared for grafting if the mastectomy defect volume immediately after Brava removal was greater than 2.5 times the pre-expansion volume.

The autologous fat transfer technique has been described.²⁰ Briefly, fat is liposuctioned manually with the LipoGraft (Lipocosm, LLC, Key Biscayne, Fla.), consisting of a 300-mmHg constant-pressure syringe (K-VAC Syringe) and two-way valve (AT-Valve) connected to a 12-hole, 12-gauge cannula. Many patients had no localized fat excess, and a thin layer of fat was harvested from a wide area through multiple needle entry sites to avoid contour irregularities. The lipoaspirate was then centrifuged at 15 *g* for 3 minutes and reinjected diffusely through multiple hypodermic needle puncture entry sites with a 14-gauge, single-hole cannula as microribbons into the expanded scaffold until interstitial fluid pressure reached 9 mmHg. Early in our experience, we estimated interstitial fluid pressure by tissue turgor, but in 2011, we began recording interstitial fluid pressure with the previously described technique.²⁰ We carefully avoided coalescence of the microribbons into lakes too wide to survive²⁸ and interstitial fluid pressure levels that restrict capillary perfusion.^{14,29,30} Unilateral operations usually take approximately 1 hour, and bilateral operations take approximately 2 hours. Some unilateral reconstruction patients underwent incisionless procedures on the contralateral side, such as fat graft augmentation, reduction, or mastopexy.

On the second or third postoperative day, the patient resumed low-pressure (20 mmHg) Brava use for as many hours per day as practically tolerated for 3 to 4 weeks as a three-dimensional stent to immobilize the grafts and hold the breasts in the expanded state. If the patient was still not satisfied with the reconstruction at 2 months postoperatively, she resumed Brava expansion for 2 to 4 weeks at the higher cycling pressures to further expand the breast and prepare it for the next autologous fat transfer; the minimum time between procedures is 8 weeks. For an irradiated breast, the minimum time is 3 months. Irradiated defects present a greater challenge, as the first two grafting sessions serve mainly to reverse radiation damage.^{19,21}

Breast volumes were determined by three-dimensional imaging at baseline, just before and immediately after each operation, and 6 months after the last operation. Some patients failed to undergo three-dimensional imaging for at least one point in the process, in which case we ignored all their volumetric data but still analyzed their photographs and complications. According to a small study, three-dimensional imaging provides acceptable accuracy for breast volume.³¹ Injected graft volumes were measured intraoperatively by recording how many 100-ml collection containers were delivered. All lumpectomy patients underwent baseline and 6-month follow-up magnetic resonance imaging. Mastectomy patients had postoperative magnetic resonance imaging scans taken to work up palpable noncystic masses.

Six patients had delayed reconstruction on one breast and immediate reconstruction on the other. However, to meaningfully analyze the data, we counted the number of breasts operated on for each indication (Fig. 1). All volumetric statistics considered only completed breasts, whereas rates of complication, cancer recurrence, and palpable mass production considered all enrolled breasts. We compared the rate of ulceration in necrosis between irradiated and nonirradiated

mastectomy breasts using a chi-square test. For bilateral reconstruction, successful completion is defined as the point at which both the surgeon and patient are satisfied with the results. For unilateral reconstruction, successful completion is defined as the point at which the size and contour of the reconstructed breast closely matches the contralateral side. In some cases, the surgeon considered the reconstruction complete but the patient requested additional surgery. The decision to grant this request was made on a case-by-case basis.

We accessed the publicly available Medicare national average reimbursement data to perform a cost analysis between reconstruction with Brava plus autologous fat transfer, deep inferior epigastric artery perforator/transverse rectus abdominis musculocutaneous flaps, and implants.^{32–39}

RESULTS

The mean body mass index was 23.5, and patient age ranged from 28 to 74 years (mean, 45 years). The mean follow-up was 2.5 years (range, 6 months to 7 years). On the 488 patients enrolled, we performed 1877 autologous fat transfers on 616 breasts. On the 427 patients who completed

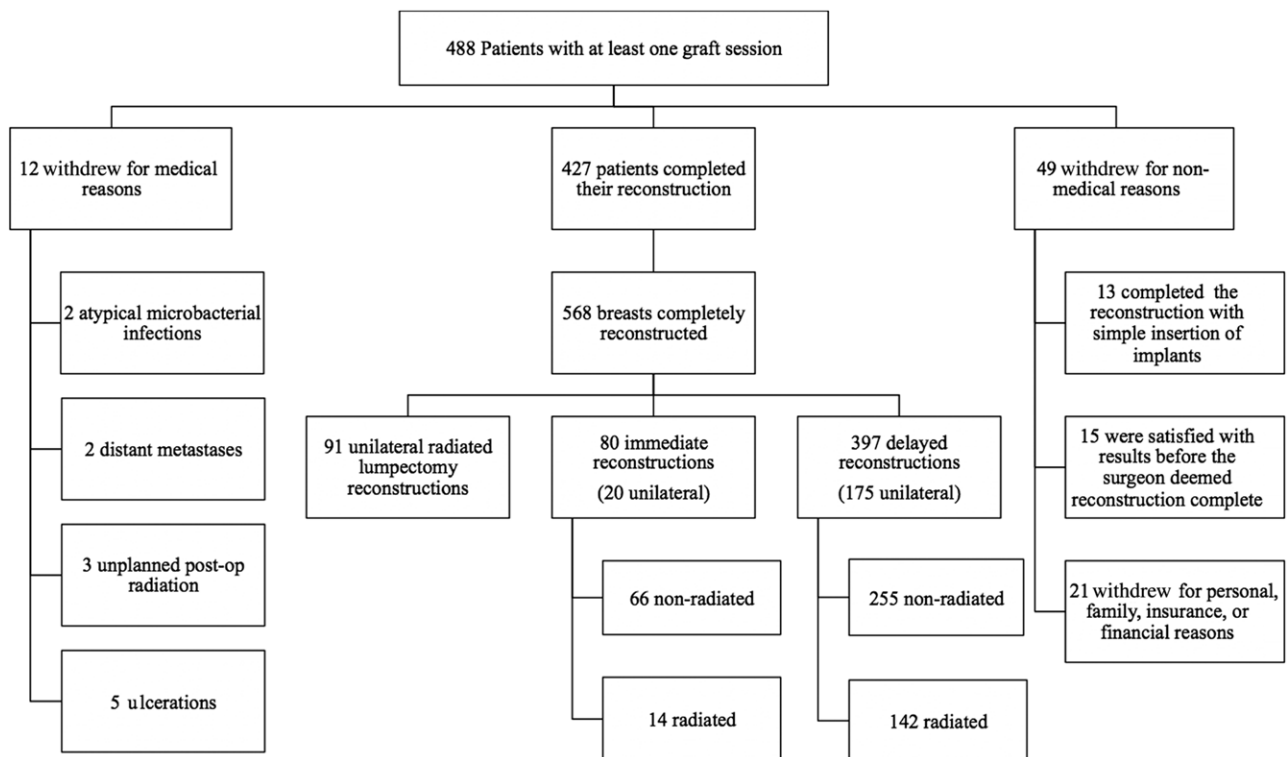


Fig. 1. Distribution of patients and breasts. Reconstructions were only considered complete when both the surgeon and patient were satisfied with the results.

reconstruction, we performed 1790 operations on 568 breasts. Of the 397 breasts in which delayed reconstruction was completed, 71 had at least one previously failed reconstruction with implants and/or flaps. Of the 80 breasts in which immediate reconstruction was completed, 27 were prophylactic.

Sixty-one patients (12.5 percent) did not complete reconstruction with Brava-assisted autologous fat transfer; 13 (2.7 percent) had already accumulated enough tissue and completed their reconstruction with a simple implant; 15 (3.1 percent) were satisfied with their results and dropped out before the surgeon considered the construction complete; 21 (4.3 percent) abandoned the treatment for insurance, financial, family, or personal reasons; and 12 (2.5 percent) dropped out for medical reasons presented below. The number of procedures completed by these patients before they dropped out ranged from one to four.

The mean number of operations per breast required to complete the reconstruction and generate a breast mound was 2.8 (range, two to five) for delayed nonirradiated mastectomy and 4.9 for delayed irradiated mastectomy (range, three to 10). The cases we inherited after prior flap or implant reconstruction failure had more scar tissue and account for the higher range of procedures. The immediate reconstruction required 2.1 grafting sessions (range, one to five) when nonirradiated, and 4.2 (range, two to seven) when the breast was previously irradiated. Reconstruction of the irradiated lumpectomy defects required 2.0 grafting sessions (range, one to four).

Overall, we grafted a mean volume of 225 ml/breast per operation. At the initial sessions, while the recipient sites were smaller and stiffer, we grafted less than in subsequent sessions, when the sites became larger and more compliant. The mean breast mound volume achieved 6 months after the last operation was 375 ml/breast.



Fig. 2. A 42-year-old woman 2 years after a bilateral mastectomy (*left*). She was not interested in having implants or flaps for her reconstruction and remained without reconstruction until she learned of this new alternative. After three Brava plus autologous fat transfer procedures and a nipple reconstruction, she regenerated her greater than 600-ml breasts and improved her body contour without any incisions (*right*). She truly feels she has regained her lost breasts; they feel soft, natural, and have recovered light touch sensation over the entire surface.



Fig. 3. (Above, left, and above, center) Preoperative markings of a 52-year-old woman before bilateral mastectomies and immediate autologous fat transfer reconstruction. She has minimal body fat localized in her thighs and flanks. (Above, right) Immediately after the mastectomy, we teased rows of fat grafts as microribbons (250 ml per breast) between the exposed pectoralis muscle fibers. (Below, left) After 6 weeks of uneventful healing, she started Brava use for 10 to 12 hours per day for 3 weeks and presented with tissue-engineered breast mound scaffolds ready for autologous fat transfer. (Below, right) Six months after this procedure, she has regenerated soft, aesthetically pleasing, and sensate breasts.

We did not analyze long-term retention as a function of initial graft volume because we do not consider percentage graft survival to be a meaningful outcome measure.¹⁴ It is not the volume of graft injected that determines the volume of graft that can survive; it is the volume, compliance, vascularity, and degree of scarring of the recipient site that ultimately will determine final graft retention.^{14,15,20}

All of the immediate reconstructions and non-irradiated reconstructions with no previous failed reconstruction attempts recovered light touch sensation (detected with a cotton wisp) over the entire surface of the regenerated breast mound. Ninety-seven percent of patients who completed reconstruction were “satisfied” or “very satisfied” with the volume, contour, and natural feel of their breasts. The operations were performed in the outpatient setting, and barring complications, patients returned to a desk-job level of activity within a few days of the procedure. Figures 2 through 8 present examples of typical cases for each indication.

Given the number of operations, the frequency and severity of complications were minor.

Five pneumothoraces occurred; one was treated with simple observation and four were treated with short-term chest tube drainage. Our incidence rate of pneumothorax was lower than that reported for traditional breast augmentation.⁴⁰ Five minor bacterial cellulitis infections developed; these subsided with medical treatment. Two difficult-to-treat, atypical, microbacterial infections occurred and required multiple debridements. Mostly early in our experience, before instituting the 9-mmHg interstitial fluid pressure limit, 18 breasts developed ulceration necrosis or mastectomy flap necrosis, requiring debridement and a setback in reconstruction. For mastectomy patients, the ulceration rate was significantly greater in irradiated breasts (6.5 percent) than in nonirradiated breasts (1.4 percent) ($p < 0.01$).

Complication rates for each indication are presented in Table 1. Immediate reconstruction patients had better results with fewer procedures than delayed reconstruction patients. Nonirradiated patients had better results and fewer complications with fewer procedures than irradiated patients. Skin-sparing and nipple-sparing mastectomies had higher complication rates. The excess skin made



Fig. 4. (Left) A 39-year-old woman presented with an irradiated lumpectomy defect and a nonhealing ulcer at the incision site. The only alternative she was offered was a latissimus flap to release the contracture, bring down the nipple-areola complex, and add volume. She did not want to lose the muscle and was reluctant to have additional scars. She used Brava for 6 weeks at low pressure. (Above, center) Despite preexpansion, her perioperative sternal notch-to-nipple distance was 15 cm on the left, compared with 18 cm on the normal right side. We placed the scar contracture under tension by tumescent injection of 250 ml of sedimented lipospiate still rich in epinephrine for the vasoconstriction effect. Then, through a multitude of percutaneous nicks and with skin hooks that place the short dimension under tension, we mesh-expanded the restrictive scar. We then injected an additional 100 ml of fat to fill the interstices created by the meshing. (Below, center) This percutaneous aponeurotomy and lipofilling (PALF) induced a 2.5-cm intraoperative gain in the sternum-to-nipple distance. (Right) At 1-year follow-up after another percutaneous aponeurotomy and lipofilling, the deformity was significantly corrected.

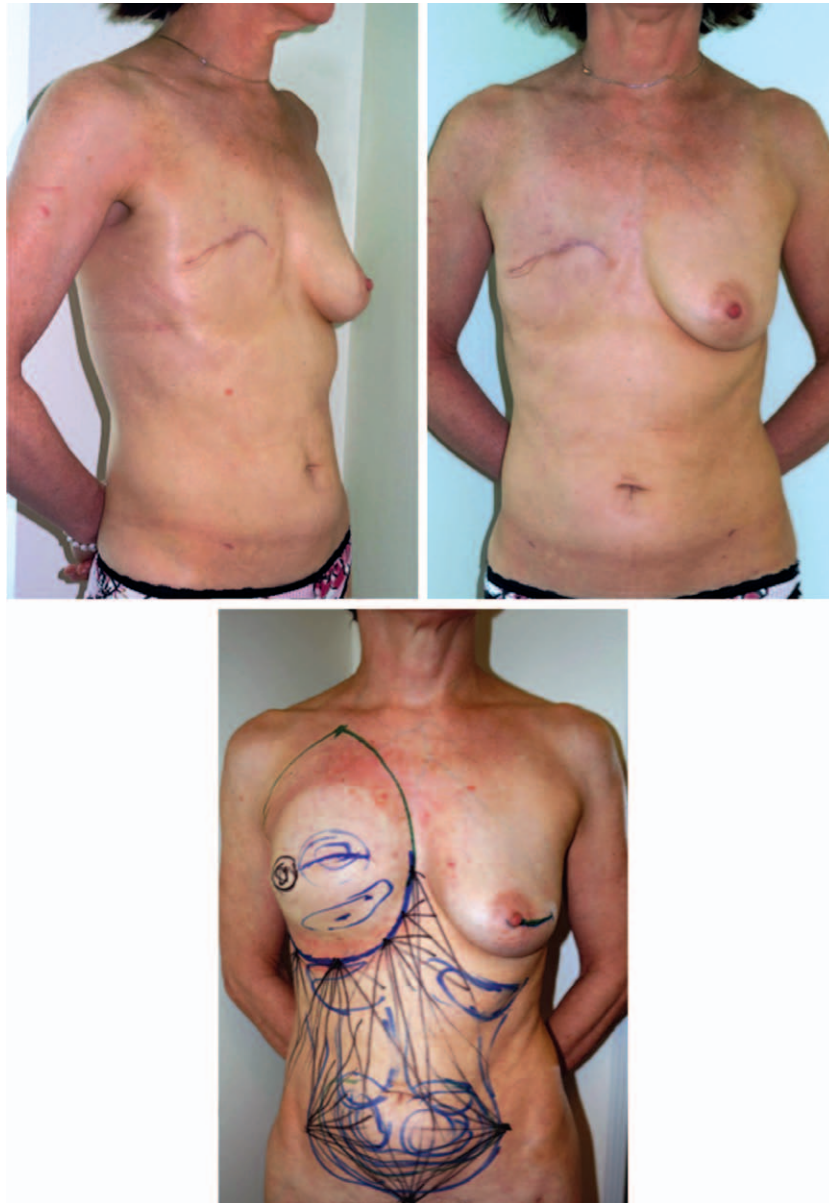


Fig. 5. (Above) A 49-year-old woman presented 1 year after a right mastectomy and positive *BRCA* diagnosis, requesting a reconstruction of her right breast and a prophylactic mastectomy with immediate reconstruction to her left breast. Before the left mastectomy, she used the Brava device for 3 weeks to regenerate a recipient scaffold over the right mastectomy defect. (Below) Markings for the expanded right mastectomy defect and for the left skin-sparing prophylactic mastectomy.

accordion-like folds, and the depth of the troughs developed difficult-to-release adhesions to the chest wall, which required additional procedures.

Palpable masses developed in 12 percent of nonirradiated breasts and 37 percent of irradiated breasts. Most of these were oil cysts diagnosed in-office by ultrasound and treated by aspiration. The remaining solid masses were worked up by magnetic resonance imaging and found to represent benign lesions. However, we kept a very high

index of suspicion, and 32 breasts (5.2 percent) underwent percutaneous biopsies. Three (0.5 percent) locoregional recurrences or new primary tumors developed over the 2.5-year mean follow-up period; two irradiated lumpectomies (2.0 percent) and one mastectomy (0.2 percent) developed a locoregional recurrence. Distant metastases were diagnosed after the second grafting session in three patients; two discontinued reconstruction.



Fig. 6. Same patient as shown in Figure 5. (*Above*) Third postoperative day: grafting the exposed pectoralis muscle at the time of the mastectomy brought fullness to the upper pole of the left defect and grafting the expanded right mastectomy generated a breast mound. (*Center*) Six weeks later, she resumed Brava expansion to both breasts for 3 weeks in preparation for a second autologous fat transfer. (*Below*) Six months after the second grafting session, her breasts had regenerated with nearly normal light-touch sensation over her reconstructed nipples.



Fig. 7. (Above) A 36-year-old woman with bilateral mastectomies and radiation therapy to the left defect. (Center) Immediately before the first autologous fat transfer procedure. Bilateral breast mounds generated by 4 weeks of Brava external expansion of the defects. The patient is brought into the operating room still wearing the Brava device. (Below) Three months after the first autologous fat transfer and just before the second procedure.



Fig. 8. The patient from Figure 7 had 4 more weeks of Brava treatment immediately before her second autologous fat transfer. (*Above*) Three months after the second autologous fat transfer and just before the third procedure. The nonirradiated right reconstruction is already complete. She only had Brava expansion of the irradiated left side for 4 weeks prior and will only be grafted on the irradiated side. (*Below*) Final reconstruction, 1 year after the last grafting session. The left irradiated mastectomy required four grafting sessions, whereas on the nonirradiated right side, a natural appearing breast mound with nearly normal sensation was regenerated in situ with only two incisionless autologous fat transfer procedures.

Completing a satisfactory breast reconstruction with traditional techniques usually requires a total of five or six operations.^{41,42} Therefore, we calculated the total cost of these alternatives assuming a conservative scenario of only three procedures on average. According to our sources,^{32–39} the total cost of a three-stage

unilateral reconstruction with a deep inferior epigastric artery perforator/transverse rectus abdominis musculocutaneous flaps is \$48,058, whereas three-stage reconstruction with expanders/implants costs \$33,657, and four-stage reconstruction with Brava plus autologous fat transfer costs \$22,458 (Table 2).

Table 1. Number of Breasts, Operations, and Complications for Each Indication

Category	Radiated lumpectomy	Immediate		Delayed		Total
		Nonirradiated	Irradiated	Nonirradiated	Irradiated	
Breasts enrolled	99	71	16	276	154	616
Breasts completed	91	66	14	255	142	568
Operations total	196	148*	63*	752	718	1,877
Operations on completed patients	182	139*	59*	714	696	1,790
Mean no. of operations to completion per breast	2.0	2.1*	4.2*	2.8	4.9	3.2
Mean no. of weeks to completion	26	25†	51†	29	64	37
Breasts with palpable masses	37 (37%)	9 (13%)	6 (38%)	33 (12%)	57 (37%)	142 (23%)
Pneumothoraces	1 (1.0%)	1 (1.4%)	0	0	3 (1.9%)	5 (0.8%)
Microbacterial infections	0	0	2 (13%)	0	0	2 (0.3%)
Ulceration necroses	2 (2.0%)	2 (2.8%)	2 (13%)	3 (1.1%)	9 (5.8%)	18 (2.9%)
Locoregional recurrences‡	2 (2.0%)	0	0	0	1 (0.6%)	3 (0.5%)
Complications§	3	3	4	3	12	25
Complication rate per operation	1.5%	2.0%	6.3%	0.4%	1.7%	1.3%
Complication rate per breast	3.0%	4.2%	25%	1.1%	7.8%	4.1%

*Not counting mastectomy and immediate fat graft procedure.

†Time after mastectomy.

‡The mean follow-up was 2.5 years.

§Surgical complications include pneumothoraces, microbacterial infections, and ulceration necroses.

Table 2. Global Health Care Cost (in U.S. Dollars) of a Unilateral Breast Reconstruction*

Procedure†	Facility (\$)	Surgeon (\$)	Anesthesiologist (\$)	Devices (\$)	Total (\$)
DIEP/TRAM					
First operation ^a	21,079‡	2862	839	0	24,780
Second operation ^b	12,478‡	1478	388	0	14,344
Third operation ^c	7069	1478	388	0	8835
Total	40,626	5818	1615	0	48,058
Implant					
First operation ^d	5990	2052	476	9960	18,478
Second operation ^e	5939	1689	388	950	8966
Third operation ^f	4680	1145	388	0	6213
Total	16,609	4886	1252	10,910	33,657
Brava plus AFT					
First operation ^g	2708	2084	476	2500	7768
Second operation ^g	2708	2084	388	0	5180
Third operation ^h	3222	1145	388	0	4755
Fourth operation ^h	3222	1145	388	0	4755
Total	11,860	6458	1640	2500	22,458

DIEP, deep inferior epigastric artery perforator; TRAM, transverse rectus abdominis musculocutaneous; AFT, autologous fat transplantation.

*Based on published³²⁻³⁹ 2012 to 2014 U.S. National Medicare average reimbursement rates. Comparative costs for three types of reconstruction: DIEP/TRAM flaps, expander/implant, and Brava plus autologous fat transfer.†Current Procedural Terminology codes: ^a14301, 19364, and 19380; ^b15770; ^c15770 and 19380; ^d15777 and 19357; ^e15770 and 19342; ^f15770 and 19380; ^g15770 and 19366; and ^h15770 and 19380.

‡Inpatient hospital: Comorbid factors and hospital category can significantly further increase this fee.

DISCUSSION

Spear and colleagues reintroduced autologous fat transfer to the breast,⁴³ and the procedure has since witnessed an explosive popularity increase.⁴⁴ It is now a well-established, safe, and effective adjunct to classic reconstruction alternatives. However, the reconstruction of an entire breast with autologous fat transfer alone required the dependable survival of megavolume grafts. Researchers have pursued this autologous fat transfer holy grail with various additives.^{45,46} We have described our approach to this problem based on a fundamental principle: megavolume graft survival requires a well-vascularized megavolume recipient site.^{14,20}

Brava plus autologous fat transfer represents a complete paradigm shift from previous techniques in that it does not rely on implanted devices or the transfer of tissue blocks. It relies on the tissue-engineering principle of generating a well-vascularized, three-dimensional scaffold by external expansion and carefully seeding it with fat microribbons.⁴⁷ We often must also convert any restrictive cicatrix into a recipient matrix by needle mesh expansion with the Rigottomy technique.^{15,20,26}

Our mean volume grafted (225 ml/breast per operation) compares favorably to reports on autologous fat transfer reconstruction without preexpansion. Reported grafted volume per

session is between 12 and 216 ml/breast, with means below 100 ml and retention volumes between 27 and 52 percent.^{16–19} Also, our recent study on cosmetic autologous fat transfer found that preexpanded breasts accept a greater volume with a higher retention rate than what is reported in studies on autologous fat transfer with nonexpanded breasts.¹⁰

Because expansion allows surgeons to graft and retain more volume per session, fewer operations are required. Our average mastectomy reconstruction required 4.5 operations per patient, which is substantially less than the average 6.5 to 6.6 operations reported for traditional procedures.^{41,42} These are all outpatient, minimally invasive, and low-complication procedures that put less stress on the patient and medical establishment.

The absolute volume of the regenerated mound is not the real challenge in breast reconstruction but rather the relative volume gained compared with the size of the original defect. A voluptuous woman with a 150-ml mastectomy defect who grew a 300-ml breast is not as impressive as a small-framed woman with a 75 ml-defect who also grew a 300-ml breast. Furthermore, our goal is to correct deformities and satisfy patients, not to obtain the greatest volumes possible. This is breast reconstruction, not augmentation. Most of the 12.5 percent of women who were considered incomplete still achieved enough volume to produce some upper pole fullness and cleavage to reveal a “social breast.”

This procedure allows prophylactic mastectomy patients to replace their cancer-prone breasts with new breasts that feel like the originals but contain none of the cancer-prone tissue. Impressively, these breasts have nearly normal sensation, which is something patients greatly value. This alternative lowers the acceptance threshold for prophylactic mastectomies, and it might also sway women to proceed with therapeutic total mastectomies and immediate autologous fat transfer reconstruction and avoid the late radiation-induced complications associated with lumpectomies. If irradiation is planned after the mastectomy, we do not offer immediate reconstruction because irradiation would damage the graft.

The ulceration rate was significantly higher in irradiated patients than in nonirradiated patients ($p < 0.01$). Irradiated breasts are more challenging because the tissues are less compliant. Knowing when to stop is the most difficult challenge. Early in our experience, we induced some ulceration necroses by overgrafting or overreleasing the scar,

resulting in high interstitial fluid pressure, poor graft-to-recipient interface, ischemia, and necrosis. Treating irradiated breasts requires much experience. Early in their experience, Uda and colleagues published a report⁴⁸ where they replicated our protocol on 14 patients and produced similar results for nonradiated breasts but concluded that the technique is not suitable for irradiated breasts. However, irradiated breasts benefit the most from this procedure because we reverse much of the radiation damage.²¹ Brava increases tissue compliance and vascularity, reducing the incidence of overgrafting. When performed properly, fat grafting irradiated mastectomies is most rewarding because of the improved results.

The regenerated mounds included a few benign palpable masses. However, their incidence was not higher than what is commonly seen in other well-accepted breast operations, such as flap reconstructions⁴⁹ and breast reductions.⁵⁰ Surgeons generally agree that they are of little concern, provided that they are monitored and remain benign.

Concern regarding cancer should be at the forefront of thoughts by any surgeon who injects anything into the breasts. Two of our 99 lumpectomy patients after 2.5-year mean follow-up developed a locoregional recurrence whereas, according to established statistics,⁵¹ we expected to see three. Furthermore, over this same time frame, only one of our 389 mastectomy patients developed a locoregional recurrence, whereas statistics would have predicted seven.^{52,53} This reduction is statistically significant. Other studies on breast reconstruction with autologous fat transfer also report low complication rates and little or no recurrence.^{54–59} Our recurrence rates compare favorably to those observed in reconstruction with flaps and implants.^{49,60,61} Recent reviews of many articles on autologous fat transfer found no report of increased cancer recurrence either.^{62,63}

With health care costs increasing rapidly, surgeons must consider the economic impact of their decisions. Approximately 118,000 mastectomy reconstructions are performed in the United States each year.^{1–3} According to our analysis, each patient who switches her reconstruction from flaps to Brava plus autologous fat transfer saves Medicare an average of \$25,600, and each patient who switches from reconstruction with expanders and implants to Brava plus autologous fat transfer saves Medicare an average of \$11,199 (Table 2). Because the current practice of breast reconstruction in the United States is approximately 69 percent implants and 31 percent flaps,³ if all breast reconstructions were performed with Brava plus autologous fat

transfer, the health care system would save approximately \$1.8 billion annually. Reconstruction with Brava plus autologous fat transfer is much less likely to cause serious complications, which increase costs astronomically. The cost differential would be much greater if we considered bilateral reconstruction and took the increased incidence of costly complications into account. Brava plus autologous fat transfer costs significantly less than traditional reconstruction methods primarily because its minimal invasiveness allows it to be performed in an ambulatory surgery center compared with an inpatient hospital.

The term “fat grafting the breasts” is a narrow description of a technique used in many operations. There is much more than simple liposuctioning and reinjecting; it is the preexpansion, the crucial ancillary moves, the craftsmanship in distributing the graft, and the adherence to fundamental principles that make this possible.¹⁴

The authors write this report after decades of combined extensive experience with traditional breast reconstruction.^{64–67} Brava plus autologous fat transfer has now essentially completely replaced these older procedures in our practices. We strongly conclude that the aesthetic quality of the reconstruction, the patient’s satisfaction with her regenerated sensate breast mound, the minimal invasiveness, the low complication rate, and the substantially lower overall costs achieved with this breakthrough tissue-engineering alternative are unmatched.^{14,15,20}

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