Megavolume Autologous Fat Transfer: Part II. Practice and Techniques

Roger K. Khouri, M.D.
Gino Rigotti, M.D.
Eufemiano Cardoso, M.D.
Roger K. Khouri, Jr., B.S.
Thomas M. Biggs, M.D.

Miami, Fla.; Verona, Italy; Ann Arbor, Mich.; and Houston, Texas

Summary: The authors describe the techniques that use the principles of fat grafting to allow them to successfully graft megavolumes (250-ml range) of autologous fat into breasts. The Brava external volume expansion device preoperatively increases the volume and vascularity of the recipient site. Low-pressure liposuction and minimal centrifugation are used to gently extract and purify the adipose tissue with minimal trauma. Even and diffuse reinjection of the fat increases graft-to-recipient interface and reduces interstitial fluid pressure. Postoperative Brava use protects the graft and acts as a three-dimensional immobilizing splint. By adhering to these techniques, we have been able to graft megavolumes of fat into the breasts of over 1000 patients and obtain substantial long-term volume retention. (*Plast. Reconstr. Surg.* 133: 1369, 2014.)

Our experience with megavolume fat grafting prompted us to adopt "the farmer" as our logo. Megavolume fat grafting is akin to sowing and supporting seeds in soil. The four S's that must be optimized are as follows:

Soil: The farmer cannot reap a large crop out of a tiny plot, and planting "super seeds" will not do much to compensate for a poor plot. The field has to be well-plowed, fertilized, and large enough to accept the amount of seeds required. External expansion with Brava (Brava, LLC, Miami, Fla.) effectively turns a small plot into a large, well-fertilized field.[1,2] Restrictive scars and fascia are analogous to rocks or tree stumps in a pasture that must be loosened and released.

Seeds: The seeds must be healthy and have retained their ability to sprout. Although much has been written about the harvesting, preparation, and supercharging of fat grafts with growth factors[3–5] and stem cells,[6] controversy remains, and no method has been shown to be clearly superior. We favor simple low-pressure liposuction and minimal centrifugation.

Sowing: We must evenly and diffusely distribute seeds throughout the field. This is like delivering a mist through a multihead sprinkling system. Sowing the seeds requires surgical craftsmanship and is a very important factor that is least amenable to scientific study.

Support: Just as the farmer protects his plantings with stakes and strings until they are able to stand on their own, the surgeon uses a postgrafting immobilizing splint. Stamping or shaking the fat grafts, or allowing them to dry, will be detrimental to all preservation efforts. Brava set at a low negative pressure functions well as a three-dimensional immobilizing splint.

It is the weakest link in this chain of events that determines the final result. The detrimental effect of this rate-limiting step seals the fate of the graft and cannot be overcome by improved handling of the other steps.

In this era of surgical evolution, we expect that many changes in our operative approach may occur. However, for the present description of successful megavolume fat grafting, this is how we are farming.

TECHNIQUE OF HARVESTING AND PREPARATION

We harvest the fat graft, using time-proven liposuction techniques with no particular donor-area

preference, although we favor fat from deposits that fluctuate least with body weight. We ask the patient to avoid gaining weight before surgery and, if possible, to lose some weight so the grafts enlarge back with return of original weight.

The Multiple Sprinklers or Evenness through Randomness

We often need to harvest fat from patients who have no localized deposits. In these situations, we need to harvest a thin layer out of a large surface and avoid donor-site contour deformities. We think of harvesting as the direct opposite of delivering. The easiest way to deliver specks evenly and diffusely over a broad expanse is to randomly sprinkle them. Delivery is much more evenly distributed as a mist randomly sprayed out of many sprinkler heads rather than a stream massively poured out of a few large-bore hoses. Similarly, because harvesting fat is a blind procedure that must be even and diffuse (we cannot directly visualize the fat harvested from the cannula tip), it is only prudent that we use the same "sprinkler system" of "evenness through randomness" in this step.

To harvest by the sprinkler system, the cannula should have a diameter in the 2-mm range for two reasons. First, this small bore will ensure that we harvest a few tiny droplets at each stroke along wide, sweeping, crisscrossing arcs. Second, the fine cannula can be introduced through needle puncture holes that need no suturing, that leave no significant scar, and therefore permit multiple (sprinkler) entry sites. As an example, to evenly harvest trochanteric fat, we use no fewer than eight entry sites with a 14-gauge hypodermic needle spread around the circumference of the mound to be liposuctioned. We do not close these entry sites.

The Palm and Pinch Test

To estimate donor-site availability, we resort to the 200-cm^2 palm measure described in Part I. By pinching and folding over the subcutaneous fat, the pinch test predicts the thickness of the available donor. Even in a thin patient, a 0.25-cm layer of fat harvested over the surface area of a palm will yield 50 ml (200 cm^2 × 0.25 cm). We can therefore harvest 250 ml solely from the anterior surface of a woman's thigh that has five "palm measures" (Fig. 1). We rarely turn away patients for lack of available fat.

Preferred Method and Devices

The available methods of harvesting and processing fat were not appropriate for megavolume grafting, so we developed the Lipografter
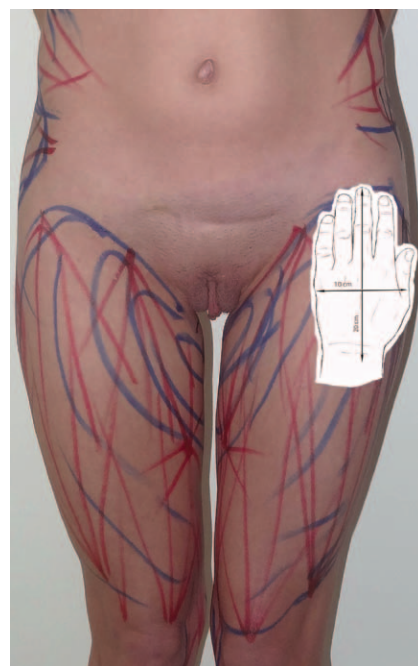
Fig. 1. The diffuse harvester and the palm measure. We use no fewer than eight needle prick entry sites to diffusely and evenly harvest fat from the anterior surface of a skinny thigh. Even in a 100-lb, 5-foot-tall woman, we can apply five palm measures to the anterior surface of the thigh and theoretically harvest 250 ml of fat per thigh.

(Lipocosm, LLC, Key Biscayne, Fla.) device, which consisted of the following:

12-Gauge, 12-Hole Harvesting Cannula

Keeping the same 12-gauge bore, we studied the effect of varying the harvesting pressure and number of cannula holes and found that fat harvesting was more efficient with a 12-hole cannula at 250 mmHg than a single-hole cannula at 750 mmHg (Figs. 2 and 3).[7] Because lower pressure is less traumatic to the fragile adipocytes, we harvest with a 12-hole, 12-gauge cannula at 300 mmHg.
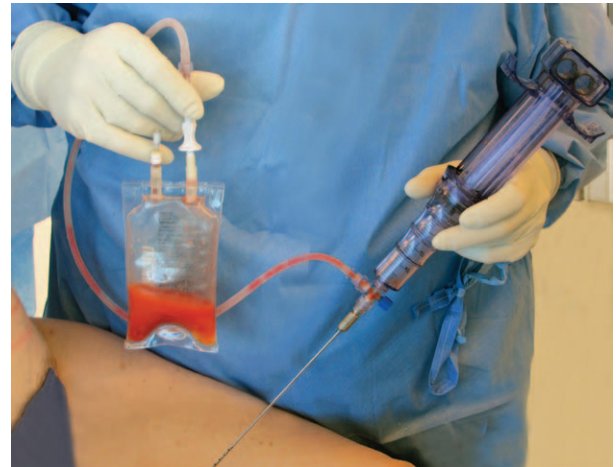
K-VAC Syringe Vacuum Source

We started using the liposuction vacuum pump at 300 mmHg but soon abandoned it, as it was not uncommon during liposuction to have one of the 12 cannula holes emerge through the skin to cause repeated high air flow in the necessarily long tubings, leading to fat desiccation. We later resorted to manual syringe liposuction, but we had no control over the pressure, and it was tiring on the operator's fingers. This led us to design a constant low-pressure syringe mechanism (K-VAC Syringe; Lipocosm) with which we are able to provide 300 mmHg vacuum along the entire excursion of the plunger (Fig. 4) because of rolled ribbon springs, similar to measuring tape coils.

Fig. 2. Five 12-gauge (2.7 mm) cannulas with increasing numbers of 1 × 2-mm holes.


Fig. 4. Lipografter set up in the harvesting mode. A 12-gauge, 12-hole cannula is connected to the K-VAC spring-loaded syringe by means of the AT-Valve (Lipocosm). Fat is drawn into the syringe as the plunger is pulled by the ribbon springs of the K-VAC at a constant 300-mmHg vacuum pressure along its entire excursion. Pushing the plunger back down re-cocks the ribbon springs, and the AT-Valve ensures that the lipoaspirate is automatically sent to the collecting bag.

Atraumatic Transfer Valve

For economy of motion, we developed an atraumatic transfer valve (AT-Valve; Lipocosm) that saves us from needing to switch syringes and cannulas. This system automatically transfers the lipoaspirate from the K-VAC syringe to the collection container (Fig. 5). This is similar to the Heimlich chest tube valve. It has a wide bore, a low pressure gradient, and rarely clogs from fibrous tissue. The valve separates the vacuum source from the collection container to limit air exposure.

Low-g Manual Bag Centrifuge

The lipoaspirate collection container is centrifuged at 15 g for 2 to 3 minutes, using a hand-cranked centrifuge. After draining the infranatant fluid, the supernatant fat is concentrated in the same collection container, which becomes the graft delivery container.

14-Gauge, Single-Hole, Spatulated-Tip Grafting Cannula

For grafting, we prefer a 2.4-mm (14-gauge) cannula with a single 1 × 2-mm hole just proximal
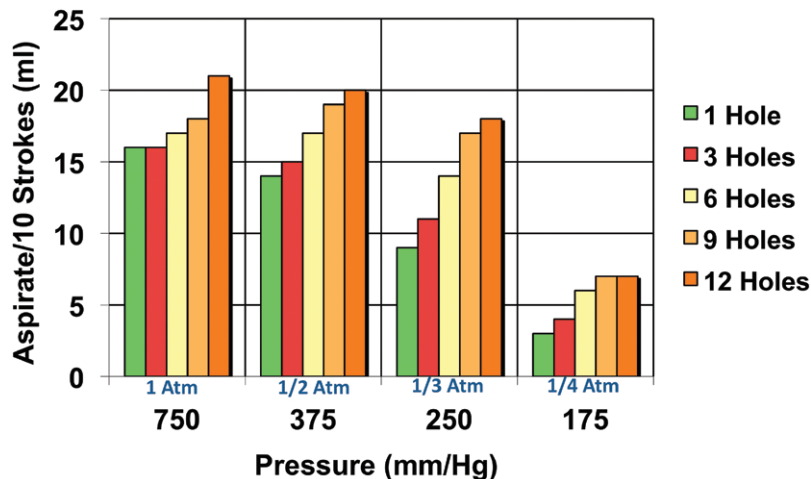
Fig. 3. Effect of aspiration pressure and the number of cannula holes on harvesting efficiency. The data show that greater fat harvest is obtained with a 12-hole cannula at 0.33 atm than with a single-hole cannula at 1 atm harvesting pressure.
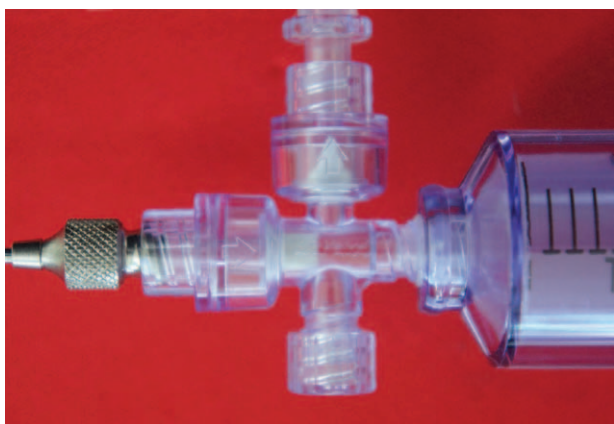
Fig. 5. AT-Valve. Lipoaspirate enters and moves through the collection process by following the direction of the *arrows*.

to a spatulated tip. It is curved at the distal third to better follow the contour of the breast topography and is either 15 or 25 cm long, depending on the grafting site.

Grafting is performed with the AT-Valve in reverse mode, again eliminating the need to switch syringes. This makes it possible for the same 3-ml syringe to continuously aspirate fat directly from the container and to repeatedly reinject it through the cannula into the breast (Fig. 6). Not having to disconnect the empty syringe, switch to a new full one, and reconnect it saves time and the personnel required to refill syringes.

The Lipografter efficiently and atraumatically collects, processes, and reinjects megavolumes of fat in a closed system with minimal manipulation of the graft. Comparing the last 900 megavolume fat-grafting procedures, with which we used the Lipografter,
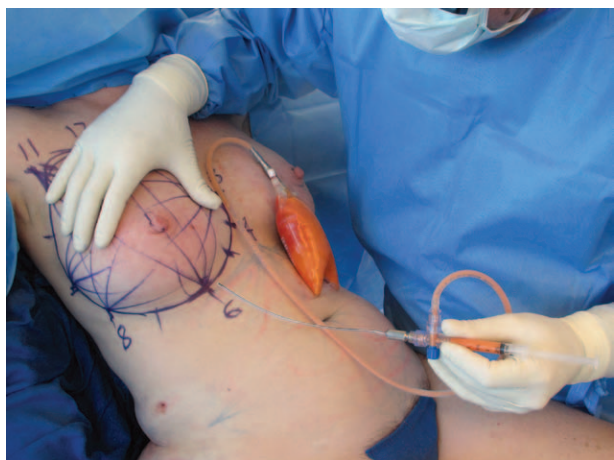

Fig. 6. Reinjection setup. A 14-gauge, single-hole, spatulated-tip grafting cannula connected to a 3-ml grafting syringe by means of the AT-Valve in grafting mode. Because of the valve, fat can be repeatedly aspirated from the collection bag into the syringe and automatically injected back through the cannula into the breast.

to the first 100 cases, with which the device was not used, we saved operative time, personnel, and supplies, with no compromise in results.

15-*g* Centrifugation

Although the standard Coleman technique of fat graft preparation requires 1200-*g* centrifugation, we, along with others who have a large experience with fat grafting the breasts, gradually moved to a low 15-*g* centrifugation method. The original 1200-*g* technique is well adapted to small-volume grafts in the face but is not well suited for megavolume grafts to the breast. Compared with the paste-like compacted graft obtained from 1200-*g* centrifugation, we propose without objective evidence that the dilute slurry resulting from 15-*g* centrifugation (Fig. 7) has the following advantages:

1. It can be injected like a sprinkler system, with more efficient distribution of fat. The farmer does not sow seed clumps.
2. Individual loose droplets have a better graft-to-recipient interface and are more likely to establish connections with the recipient capillary network than when crowded in a paste.
3. Lipoaspirate contains plasma, platelets, and beneficial growth-promoting factors that may get lost under stronger centrifugation.
4. Grafting more dilute fat allows for "lipotumescence," which places the restrictive fibrous bands under tension for easier release by nicking with needle tips (Rigottomy technique, described below).
5. Epinephrine from the donor-site tumescence is preserved in the dilute suspension, leading to vasoconstriction in the recipient
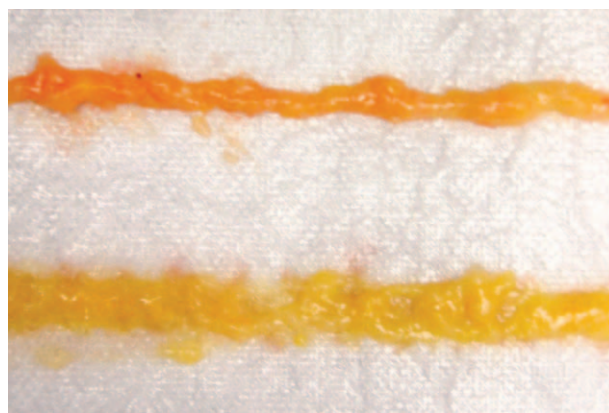
Fig. 7. Paste-like appearance of compacted fat from lipoaspirate centrifuged at 1200 *g* (*above*), compared with the loose slurry of lipoaspirate centrifuged at 15 *g* (*below*).

for bloodless tunneling of the cannula and Rigottomy.

6. The dilute suspension provides an added margin of safety against overgrafting, because part of the grafted volume is fluid that is readily reabsorbed.

7. Loose lipoaspirate is less likely to clog the thin-bore grafting cannula.

8. 1200-g centrifugation can only process modest volume aliquots at a time and is impractical for megavolume graft preparation.

9. Because we favor extensive tumescence of the donor areas, the lipoaspirate is rarely bloody, and the cell suspension can thus sediment more rapidly with low-g forces.

10. 15-g centrifugation is less tissue traumatic.

TECHNIQUE OF FAT GRAFTING

Grafting is performed by injecting microribbons of fat as rows carefully inserted in separate planes. Except for the breast parenchyma, which can be dense and potentially contaminated from the ductal flora, we graft all tissue planes: subpectoral, intrapectoral, subglandular, subdermal, and subcutaneous. The latter two are the preferred sites, as they expand most with Brava, and augmenting these most superficial planes yields more projection than deeper planes. Similarly, golf balls yield more projection when placed under the bed sheets than when placed under the mattress. Grafting the pectoral muscle is ideal in immediate reconstruction because the restrictive fascia has been removed and grafting can be performed under direct vision (Fig. 8). Grafting the retropectoral space should be performed cautiously with the tip of the curved cannula pointing upwards to avoid a pneumothorax.

Sprinkler Delivery System of Evenness through Randomness

Fat grafting to the breast is a blind procedure; we do not see the tip of the cannula and can only guess at the evenness of graft distribution. We want to keep every delivered microribbon of fat in a separate tissue channel and avoid coalescence of our inserted microribbons into a lake. Although we strive to follow an organized pattern of grafting to avoid repeated delivery to the same area and undergrafting others, we realize that our best bet for evenness is random sprinkling out of multiple heads.

In a small anatomy laboratory study, we grafted cadaver breasts with methylene blue–stained fat and dissected the specimens. The best
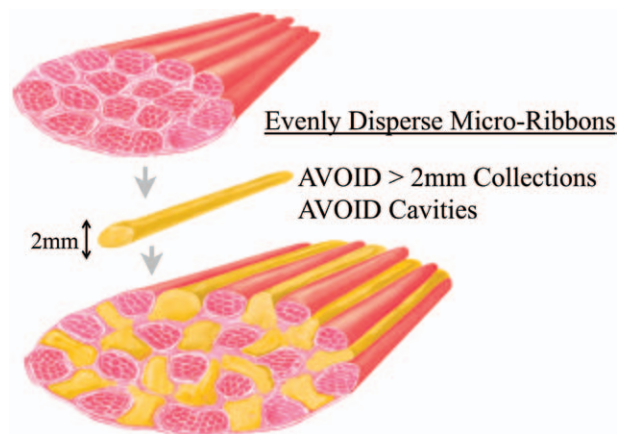
Fig. 8. Grafting microribbons of fat along the muscle fibers to avoid creation of cavities where the fat might collect into pools wider than 2 mm.

graft distribution occurred when grafting was performed with the smallest syringe through multiple entry points.

To have a reference, we use a clock-face marking of the breast (from 12 noon, clockwise around the breast). In the lower half, we fan out multiple radial passes a few degrees apart, placing the ribbons in either subdermal or deeper subcutaneous spaces, generally alternating each plane for odd- or even-numbered clock-face hours (Fig. 9). The 9- to 11-o'clock positions are ideal for grafting the pectoralis muscle. The upper half is reserved for the deepest muscular and submuscular planes, as the venetian blinds configuration of the ribs makes it less likely to enter the chest when driving the cannula caudally. These injection entry sites are made with a 14-gauge hypodermic needle.

Each pass with the 25-cm cannula delivers approximately 2.5 ml, or 0.1 ml/cm. At this rate of 0.1 cm^3/cm, the ribbons of fat delivered have a 0.1cm^2 cross-section inside a recipient cleft around 2.5×4 mm. This ensures that no fat cell is more than 1.3 mm from a recipient capillary.

When to Stop: Monitoring Interstitial Fluid Pressure

Imperative in the fat-grafting process is knowing when to stop. The surgeon must understand that a threat to the overall success is imminent if the interstitial fluid pressure increases to compromise the budding microcirculation. Despite the preoperative estimate of how much to harvest and how much could be grafted, it is important to monitor the recipient site and ensure that it maintains nearly normal tissue turgor. We must avoid the peau d'orange of subdermal tension, keeping in mind that often less is best.
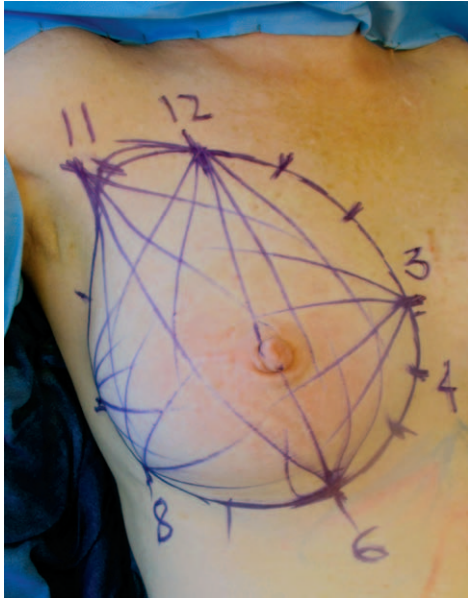
Fig. 9. Clock-face pattern of injection sites for the sprinkler delivery system. Through each needle puncture wound entry around the clock's face, we perform 10 to 12 radially fanning out injection passes in alternate grafting planes.

In our first few hundred megavolume fat grafts, we learned what the maximally tolerable tissue turgor subjectively feels like and stopped grafting when this was reached. In the past 100 cases, we intraoperatively inserted a catheter into the recipient and connected it to a pressure transducer to monitor the interstitial fluid pressure during grafting (Fig. 10). Comparing objective numbers with our past subjective experience, we settled on 9 mmHg as the uppermost limit. This is lower than the 15-mmHg capillary blood pressure and slightly higher than the 6-mmHg physiologic limit of interstitial fluid pressure[8] because we are grafting a dilute slurry, which is expected to be partially resorbed. Establishing this objective endpoint allowed us to consistently produce better results by avoiding pressures that restrict blood flow and cause microribbon coalescence.

TREATMENT OF SCARS AND RESTRICTIVE APONEUROSIS

Rigottomy and Jackhammer Grafting Technique: Cicatrix to Matrix

In cases of contracted scar tissue, as seen in breasts with infection, radiation scarring, scar contracture from previous surgery, or congenital constriction bands (as seen in tuberous breast), we found it necessary to release the contracture at the time of fat grafting. The temptation to simply excise the scar or perform a fasciotomy-like relaxing incision must be resisted, because this will result in the formation of a larger cavity which, if grafted, will lead to a large pool of fat that lacks a stromal/vascular scaffold to provide an optimal graft-to-recipient interface. Cavity is the enemy and should be avoided at all cost.

To release and stretch-expand a scar without creating a cavity, we use a technique we call "Rigottomy" (after its founder, Gino Rigotti). With 18-gauge needles, we create multiple tiny nicks inside the contracted tissue. The result is not unlike the meshing of a skin graft, only it occurs as a three-dimensional release rather


Fig. 10. Maximal graft capacitance of the recipient breast is determined by monitoring interstitial fluid pressure. A catheter inserted into the recipient breast (*1*) samples the interstitial fluid pressure, which is transmitted through the column of saline in tubing (*2*) to the pressure transducer (3) adjusted to be at the same level as the catheter because of the laser pointer level (*4*). The pressure reading is transmitted through a cable (*5*) to the display monitor (*6*).

than in a two-dimensional plane. Compared with the standard scar incision release that opens tissue planes that would be inhospitable to fat grafts, three-dimensional meshing enlarges a tight solid scar into a beehive-like structure with microcavities, into which the fat graft can enter and survive by diffusion until neovascularization occurs.

This Rigottomy expansion technique is typically performed after some jackhammer grafting. Compared with the gentle, organized, fan-like passages of the cannula in the healthy subcutaneous tissue, in the jackhammer grafting, the cannula forcefully pokes multiple tunnels into the scar and injects them with dilute lipoaspirate to induce tissue tumescence that places the fibrous scar bands under tension. The needle tip can then nick the remaining taught fibrous bands that still restrict inflation and expansion. The idea is to stretch-expand the hard fibrous tissue by opening inside it hundreds of tiny 2-mm cavities where the injected fat can survive, and avoiding the temptation to make wide sweeping cuts that create large cavities where the fat will pool and die. This three-dimensional meshing of the scar expands the volume of the recipient bed, which in turn brings down the interstitial fluid pressure into the acceptable range for graft survival (Fig. 11).

With this combination of jackhammer tumescent grafting and Rigottomy, a rock-hard scar can be loosened, stretched out, expanded, and turned into a beehive or three-dimensional chicken wire–like recipient scaffold for the fat grafts. The restrictive cicatrix thus expands into a receptive matrix for regenerative fat grafts. By seeding the resultant microcavities with microfat droplets, the brick becomes more like the fat around it.
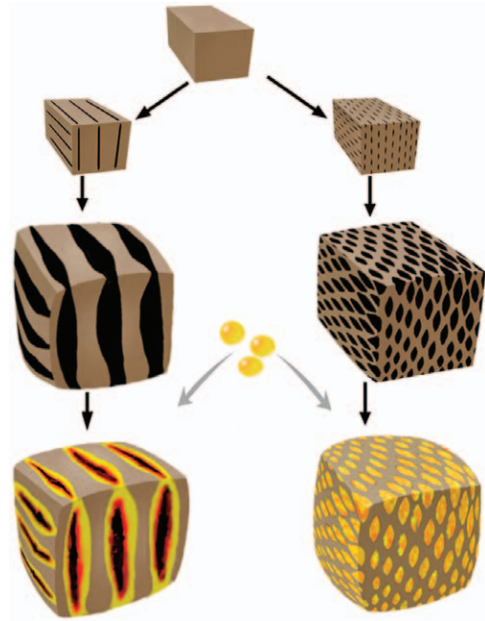

Fig. 11. Whereas conventional release with subcision cuts and relaxing incisions creates cavities where the fat grafts die from lack of adequate graft-to-recipient interface (*left pathway*), three-dimensional mesh expansion through a series of small nicks or cuts creates microcavities that transform the cicatrix into a matrix receptive to fat graft (*right pathway*).

Repeating the procedure effectively reduces the scar (Fig. 12).

Percutaneous Aponeurotomy Lipofilling

We have named the procedure of two-dimensional release of a restriction followed by grafting percutaneous aponeurotomy and lipofilling, or PALF. When scars, endogenous fascia, and subcutaneous aponeurotic fibers restrict tissue advancement, we classically resort to flap tissue transfers. Percutaneous
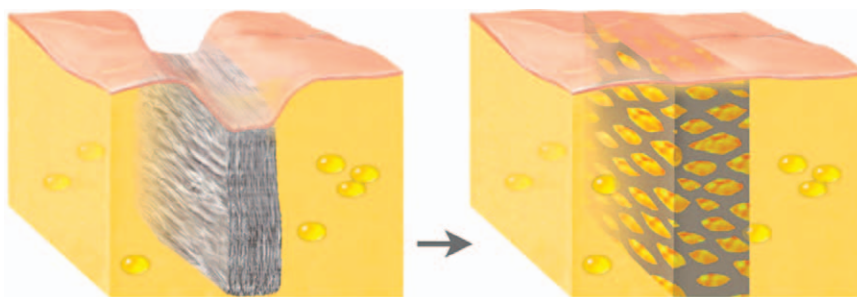
Fig. 12. Cicatrix to matrix. A scar is like a restrictive solid brick wall tethering down the tissues and separating two fatty compartments. Mesh expansion of the brick wall with Rigottomies and jackhammer grafting loosens the scar and creates openings or microcavities where the fat graft can enter and survive. The cicatrix becomes a matrix for fat grafting. The result is a scar that is less restrictive, less brick-like, and closer to normal fat. Repeating the process can altogether eliminate the scar.

aponeurotomy lipofilling gives us another option; it is the regenerative alternative to the flap. With our ability to mesh-expand the structure that limits tissue advancement, turn it into a three-dimensional fibrovascular recipient scaffold, and seed it with cells harvested by liposuction, we are capable of generating in situ the tissue needed for the reconstruction. Our reconstructive efforts are no longer limited to "borrow from Peter to pay Paul." We can now let Paul grow on his own. This broadly applicable percutaneous aponeurotomy and lipofilling (PALF) can thus be considered instead of the traditional incision-needing, scar-creating, and complication-prone flap, thus providing nearly complication-free regeneration of tissue (Fig. 13).[9]

POSTGRAFTING SUPPORT

Postgrafting support that immobilizes and maintains open the graft-expanded space is important for many reasons:

1. Immobilization of the graft is crucial to revascularization.
2. It is accepted in plastic surgery that after releasing a contracture and grafting the defect, to prevent recurrence, it is imperative to preserve the expanded space in an open state by splinting it in extension until the graft matures.
3. Tension encourages growth of grafted cells, even in a Petri dish.[10,11]
4. Outward mechanical forces increase skin graft take and accelerate wound healing.[12]
5. Outward mechanical forces increase tissue volume and vascularity[2] to improve graft survival.
6. Splinting maintains a water-rich empty proteinaceous matrix, which is known to induce adipogenesis.[13]
7. Tension (mechanotransduction) is known to up-regulate a host of beneficial growth factors.[14]
8. Tension generates the vitality of the otherwise dormant endemic stem cells.[15]

In our clinical experience, postoperative splinting and support improve fat graft survival and deformity correction. Lectures on these principles and live surgery videos of these techniques are available at the *Plastic and Reconstructive Surgery* Web site.[16,17]

Farmers fed mankind for millennia, knowing very little about the basic science of agriculture that is still being researched today; they only knew
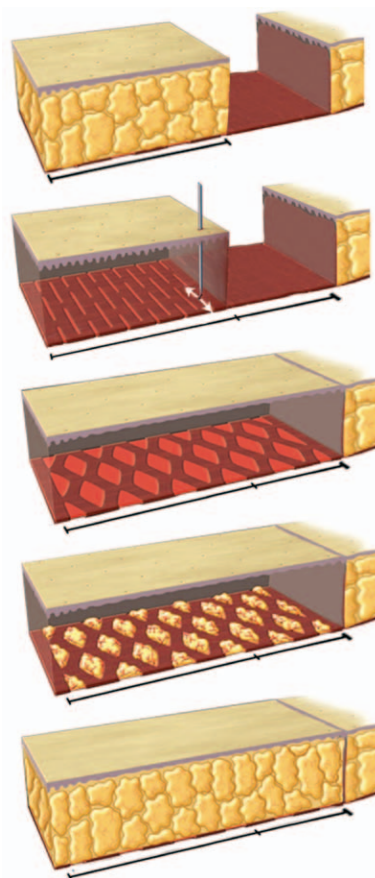
Fig. 13. The percutaneous aponeurotomy lipofilling alternative to the flap. (*Above*) Wound closure is restricted by the stretching limit of the adjacent tissue. (*Second from above*) The tip of an 18-gauge needle can percutaneously, without leaving a scar, selectively mesh the restrictive endogenous subcutaneous aponeurosis that is under tension to generate a pattern of nicks akin to a meshed skin graft. (*Third from above*) Expanding the meshed aponeurosis allows the adjacent tissue to advance and close the defect and transforms the restrictive aponeurotic fascia or scar into a recipient scaffold for fat grafts. There is no tension on the closure, no undermining of tissue, and no large cavity formation. As with meshed skin grafts, expansion is limited by the size of the transverse nicks. Too much expansion with larger cuts leaves behind larger cavities inhospitable to the grafts; expansion greater than 20 to 30 percent will lead to graft failure. To close larger defects, we have to mesh-expand over a wide area and/or repeat the percutaneous aponeurotomy lipofilling procedures 2 to 3 months apart. (*Second from below*) Small interstices within the meshed aponeurosis become seeded with fat graft droplets where the fat can survive. (*Below*) As the grafts mature, the defect is reconstructed with regenerated tissue. This is in vivo tissue engineering: fibrovascular scaffold created by the mesh and populated by liposuctioned cells.

that when they carried out their works in specific ways (following the principles of the four S's), their crops survived and grew. Similarly, the good

surgeon knows that if he or she applies these four S's, his or her grafts will succeed long before the day biologists can fully explain the immense intricacies of "how" and "why."

Roger K. Khouri, Jr., B.S.
1113 Freesia Court
Ann Arbor, Mich. 48105
rkkhouri@med.umich.edu

REFERENCES

1. Khouri RK, Eisenmann-Klein M, Cardoso E, et al. Brava and autologous fat transfer is a safe and effective breast augmentation alternative: Results of a 6-year, 81-patient, prospective multicenter study. *Plast Reconstr Surg.* 2012;129: 1173–1187.
2. Heit YI, Lancerotto L, Mesteri I, et al. External volume expansion increases subcutaneous thickness, cell proliferation, and vascular remodeling in a murine model. *Plast Reconstr Surg.* 2012;130:541–547.
3. Topcu A, Aydin OE, Ünlü M, Barutcu A, Atabey A. Increasing the viability of fat grafts by vascular endothelial growth factor. *Arch Facial Plast Surg.* 2012;14:270–276.
4. Eppley BL, Snyders RV Jr, Winkelmann T, Delfino JJ. Autologous facial fat transplantation: Improved graft maintenance by microbead bioactivation. *J Oral Maxillofac Surg.* 1992;50:477–482; discussion 482.
5. Shoshani O, Livne E, Armoni M, et al. The effect of interleukin-8 on the viability of injected adipose tissue in nude mice. *Plast Reconstr Surg.* 2005;115:853–859.
6. Sterodimas A, de Faria J, Nicaretta B, Boriani F. Autologous fat transplantation versus adipose-derived stem cell-enriched lipografts: A study. *Aesthet Surg J.* 2011;31:682–693.
7. Khouri RK, Cardoso E, Kuru M. A practical lipo-grafter for lipo-grafting. Paper presented at: 20th Meeting of the European Association of Plastic Surgeons; May 28–30, 2009; Barcelona, Spain.
8. Guyton AC. *Textbook of Medical Physiology.* 10th ed. Philadelphia: Saunders; 2000.
9. Khouri RK, Smit JM, Cardoso E, et al. Percutaneous aponeurotomy and lipofilling: A regenerative alternative to flap reconstruction? *Plast Reconstr Surg.* 2013;132:1280–1290.
10. Buckley MJ, Banes AJ, Levin LG, et al. Osteoblasts increase their rate of division and align in response to cyclic, mechanical tension in vitro. *Bone Miner.* 1988;4:225–236.
11. Petermann AT, Pippin J, Durvasula R, et al. Mechanical stretch induces podocyte hypertrophy in vitro. *Kidney Int.* 2005;67:157–166.
12. Moisidis E, Heath T, Boorer C, Ho K, Deva AK. A prospective, blinded, randomized, controlled clinical trial of topical negative pressure use in skin grafting. *Plast Reconstr Surg.* 2004;114:917–922.
13. Doldere JH, Thompson EW, Slavin J, et al. Long-term stability of adipose tissue generated from a vascularized pedicled fat flap inside a chamber. *Plast Reconstr Surg.* 2011;127: 2283–2292.
14. French AS. Mechanotransduction. *Annu Rev Physiol.* 1992;54:135–152.
15. Gilbert PM, Havenstrite KL, Magnusson KE, et al. Substrate elasticity regulates skeletal muscle stem cell self-renewal in culture. *Science* 2010;329:1078–1081.
16. Khouri RK. Clinical and scientific basis for autologous fat transplantation in breast augmentation and reconstruction. Presented at: 45th Annual Baker Gordon Symposium; February 10–12, 2011; Miami, Fla. Available at: http://journals.lww.com/plasreconsurg/pages/videogallery.aspx?videoId=194&autoPlay=true. Accessed April 3, 2014.
17. Khouri RK. Autologous fat transfer breast augmentation: A surgical video. Presented at: 45th Annual Baker Gordon Symposium; February 10–12, 2011; Miami, Fla. Available at: http://journals.lww.com/plasreconsurg/pages/videogallery.aspx?videoId=192&autoPlay=true. Accessed April 3, 2014.